THE NATURE-LOVERS' SERIES

MOUNTAIN & MOORLAND

PROF. J. A. THOMSON

MOUNTAIN AND MOORLAND

A Moorland Scene.

NATURE LOVER'S SERIES

Edited by W. P. PYCRAFT (*of the British Museum*).

MOUNTAIN AND MOORLAND

BY

J. ARTHUR THOMSON, M.A., LL.D.

REGIUS PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF ABERDEEN
AUTHOR OF "SECRETS OF ANIMAL LIFE," "THE WONDER OF LIFE,"
"BIOLOGY OF THE SEASONS," "DARWINISM AND HUMAN LIFE,"
"HEREDITY, "INTRODUCTION TO SCIENCE,"
"THE SYSTEM OF ANIMATE NATURE," "OUTLINES OF ZOOLOGY"

WITH COLOURED FRONTISPIECE AND OTHER ILLUSTRATIONS

LONDON
SOCIETY FOR PROMOTING CHRISTIAN KNOWLEDGE
NEW YORK: THE MACMILLAN CO.
1921

PREFACE

THE purpose of this little book is simple enough, but difficult of achievement. It is meant to interest intelligent people, holidayers included, in what is to be seen and enjoyed, enquired into and understood, in the wonderful Aladdin's Cave of the Mountains and Moorland. There is no risk of interfering with rest and recreation in getting interested in such subjects as mountain-making or peat-making, the secret of the heather, or the different ways of meeting the severe winter on the hillsides.

The fact is that people who do not at least nibble at the endless brain-stretching, but not vexatious, problems which their surroundings present are missing a good deal both of the meaning and the fun of life. One of the difficulties, we believe, in the way of those who are organically interested in the world without is to make a start; and one of the objects of our simple studies is to supply the requisite introduction and a jumping-off place for individual investigations. Each of our chapters may serve as a centre around which personal information will gather and crystallise, till the centre is hidden. References here and there to books may be of use as guide-posts to further adventures in the unending endeavour to understand our environment.

J. ARTHUR THOMSON.

THE UNIVERSITY,
ABERDEEN,
September, 1920.

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MOUNTAIN AND MOORLAND

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OVER THE HILLS AND FAR AWAY

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WE begin our study of Mountain and Moorland with a walk we had one summer day in the West Highlands, for this plunges us into the middle of things, and it may serve better than a formal introduction to illustrate the problems we have to discuss.

We were wakened by skylarks soon after sunrise, and everything seemed new in the early morning light. It is partly, we suppose, that the sun's rays are at first low and horizontal, they show things "in a new light." Perhaps there is something in the excitement of getting up a good deal earlier than usual. In any case the countryside seemed transfigured that morning, and we got a surprise when we opened the door. For there on the step, looking at us out of big moist eyes, was a mother Red Deer—in other words, a Hind. At this time of year the Stags or males are on the heights; the Hinds and the Fawns feed in the valleys. We suppose she had come to the door to lick a dish that the ducks and hens got scraps from, for Red Deer are fond of salt; or perhaps she had been trespassing in the garden. The Red Deer feed mostly in the mornings and evenings, resting and chewing the cud during the day among the heather. The Hind looked at us full in the face for a minute, and then without any flurry turned and trotted off. We thought the day had begun well, and we made a start.

It is no bad sign for the summer day's excursion when the distant tops of the hills are veiled in mist. The day is very young yet and the high rocks are cold; therefore it is that the air round about them gets chilled and the water-vapour condenses, becoming visible as mist. Everyone knows how the water-vapour of the breath condenses in the air on a winter morning. The mist on the mountain-tops far ahead of us is a thin cloud, always changing as the air-current flows slowly or quickly on, and many of the minute particles of water suspended in the air sink on to the rocks and lichens and mosses. Some of the water will evaporate again and steal off into the air when the sun's rays begin to warm things up; some of it will soak down to the roots of the plants and will be used in part to build up starch and similar substances; while a residue will pass from the plant's leaves into the air once more. Some of it, trickling from blade to blade, will collect in a tiny pool no bigger than a saucer, and there a Ptarmigan may slake its thirst; but of this water used by the bird some will return to the air in the hot breath; or if it were used by a mammal it might pass off not only in the breath, but also in sweat and by the kidneys. Finally, some of the water, escaping all capture by bird or beast, by plant or by mineral matter, will pass slowly down and down through crevices and underground runlets, until it drips over a mossy bank into a stream and hurries on to the sea. From the sea in the heat of the day water will rise again as mist, and be spread through the travelling air, until the clouds break once more on the mountain-side. So, as we set out on our walk over the hills, we start with the big idea of the *circulation of matter.* As the old Greek philosopher Heraclitus said, "all things flow"; and surely that is above all true of water.

After leaving the highroad we skirted a gently sloping field where bullocks were lying half awake, and then we jumped over a wall on to the real hillside. We found ourselves in a forest of bracken, which seemed to be spreading over the short grass. It was a thicker and a bigger forest than when we were there before, and unluckily that is just what is happening over wide areas of hillside and hillfoot. The bracken is an extraordinarily robust fern, very resistant to difficulties and emphatically aggressive. It is spreading over and ruining much fine pasture. In some places it is actually killing the heather. Here, then, we have an instance of the stern struggle for existence, a struggle for foothold and food and light; and it is not the higher plant but the lower that is surviving. Something will need to be done to check the intrusions of the bracken. These are sometimes met by cutting and by spraying with sulphuric acid, but this costs time and money. Perhaps there is more hope in discovering new uses for the bracken, so that there will be positive inducement to farmers to spend labour in cutting. It makes good bedding for cattle; it has strong antiseptic qualities, and makes good stuff for storing special seed-potatoes in; the young shoots might be fed to pigs and cattle; there is a considerable quantity of potash about the plant. But is there not something very promising in the results of a few experiments which have shown that the fish-yield of freshwater lochs can be greatly increased by pitching cartloads of bracken into the waters? The slow decay of the fern, due, as always, to bacteria, promotes the multiplication of animalcules, on which small crustaceans and the like depend. And thus the fishes are fed. This, again, is the idea of the circulation of matter. Nothing is ever lost, but passes from one embodiment or incarnation to another. For so the world goes round. It may be that bracken cast upon the waters will return in many days in the form of fishes, if not of loaves. The experiments referred to should be continued, for we ought to get more bread out of the freshwaters than we do, and the encroachments of bracken on good pasture must be checked.

As we made our way along the side of a small valley we were alternately on firm and on soft ground, on promontories with loose stones and in bays with bog-moss and rushes. On the hard ground there were Bluebells and Blue Scabious and gorgeous Ragworts. The last would seem more beautiful if we saw them less frequently and did not call them weeds. On the soft ground there were stately Valerians and squat Butterworts and other plants that like plenty of moisture. In both places there were thistles and on the thistles there was cuckoo-spit—just about the last of it for the season, for it gets rarer after midsummer. There is no commoner sight than these frothy masses on plants, and many people look at them with repulsion. But that is because they do not know the story. There are various kinds of cuckoo-spit, all made by the young stages of small plant-sucking insects (Frog-

Hoppers) distantly related to Cicadas. One of the commonest is called *Aphrophora spumaria,* and we see it when we brush aside the froth with our finger. It is a greenish creature with a rather squat body, on the under side of which posteriorly there is a middle groove which is used in a curious way in capturing air. Briefly told, the story is this: The young Frog-Hopper pierces the skin of plants with a proboscis enclosing sharp needles; it sucks up the sweet sap and it takes so much that it overflows with it; it works its posterior body up and down and with the help of the posterior groove whips the sugary sap into a foam, just as the cook beats up white of egg by entangling air in it with a knife. At the same time it secretes a little wax from glands near its tail. Now the watery, sugary sap, which has passed through the Frog-Hopper's food-canal and brought a ferment with it, makes when it is mixed up with the wax a kind of soap, and when this is mixed up with air it makes bubbles. Thus the young frog-hopper is hidden amidst its own soap-bubbles; it is kept moist during the heat of the day; and it seems safe from almost all interference. After it has attained its full size it leaves the froth as a winged insect able to take big jumps among the herbage, and it is to this, of course, that the word "frog-hopper" refers. When the change to the full-grown form is accomplished there is no more blowing of soap-bubbles; and we can understand, therefore, why we see less and less cuckoo-spit as the summer goes on. We have not been able to do more than outline the story, but surely we have said enough to show that a very common thing, which people who do not know any Natural History sometimes look at with real or pretended disgust, may have more than a touch of romance. But we must get on with our walk.

The glens on this range are in the springtime quite lively with Cuckoos, but these naughty birds have been silent for weeks now, and the parents, without their children, will soon be leaving for the South. Is there any more puzzling bird? The mother lays an egg on the ground, takes it up in her mouth, flies along the hedgerow or meadow with it, and deposits it in the foster-parent's nest. The Cuckoo's egg is often conspicuously unlike the foster-parent's—and there are scores of different foster-parents—but sometimes it is like an exact copy in colour and pattern and everything save the texture of the shell. Long before the young Cuckoos are ready to leave our shores, the parent birds, who evade parental responsibilities, have migrated. Among all our migrants this is the only case in which the seniors leave our shores first in their flight southwards. How do their offspring find their way, especially when their foster-parent is not a migrant? Why do little birds combine to mob a Cuckoo? Can they really think that it is like a hawk? Then the nestling is so strange. It is so sensitive for the first eleven days in a hollow on its back that a touch provokes a violent shrugging and struggling. Everyone knows that this dog in the manger, if one may use the term for a young bird, gets the foster-parent's eggs on to its back and pitches one after another out of the nest and that it will do the same to a fellow-nestling belonging to the foster-parent. These are a few of the Cuckoo puzzles that rise in our mind as we go up the hill. They may be followed up in our "Secrets of Animal Life" (London, 1919).

Keeping a little way ahead of us, for more than half a mile, as we began the ascent, there was a Wheatear (*Saxicola œnanthe*), flitting restlessly from rock to rock. In reality, there was probably a succession of Wheatears. It is a very conspicuous bird when it flies, because of the bright white splash above the tail, which may possibly serve to direct the hawk's aim away from more vulnerable parts. There is no doubt that hawks harry Wheatears, but we wonder if there is not as much danger as gain in the white rump. Moreover, the bird is always advertising its presence by uttering the loud "chack, chack," like the sound of stones knocked sharply together. The fact is that it finds safety in its cleverness in seeking concealment in small holes or in bushes. Perhaps the white rump is only an additional decoration to the very handsome plumage of a very alert bird. The Wheatear is one of our earliest summer visitors, arriving about the middle of March; it makes a grass nest lined with hair and feathers in the recess of a dry stone-wall, in a discarded rabbit's burrow, or in a peat-stack on the moor; and, however reckless the bird may be in calling attention to its own presence, it is most scrupulously careful not to give away the secret of the brood. We always associate the Wheatear with rough ground on which whins grow, where there are heaps of loose stones and outcrops of lichen-covered rock; but it goes far up the hills, hunting for spiders and small insects. It sometimes finds a good many very minute snails which are much appreciated.

The Wheatear seemed a particularly cheerful bird that morning, and that is its character. The courting gaiety of the male is beyond description. It is expressed in remarkable feats of flight, in dances, in polite ceremony, and in singing competitions. There is also a good deal of sparring between rival males, but it does not seem to come to much. What strikes the unprejudiced observer is the note of gaiety; so it is strange to find that in many parts of the country the Wheatear is regarded as a bird of ill omen, especially if it says "t'schach, t'schach" when seated on a stone, which is just what it usually does! The explanation has been offered that the bird frequents lonely places, cairns, burial mounds, and old churchyards. Perhaps mis-educated people hear in the "chack, chack" the sound of the mason carving their name on a tombstone!

There was nothing for it now but a long pull up hill, following a track among the heather, and as we wished to get on before the day grew warm we did not stop walking till a good hour had passed. Then, having earned a rest, we stretched ourselves on a slope among the heather and began Natural History again. We saw that there was round about us quite a bustle—a silent bustle—of small insects and spiders, not to speak of small snails and slugs, besides centipedes and millipedes; and we knew that for every creature we saw there were a dozen that we missed, and a score that we could not see. Dr. Shipley cut up some branches of heather and put them in water in a centrifugal machine, and then counted all the little creatures which the forcible washing scoured off the twigs. They were legion; there is really a bustle among the heather.

We saw, for instance, a mother-spider about the size of a green pea, who carried about under her breast a ball of silk. This is called her cocoon, but it is very different from the cocoon of the butterfly or moth, such as that yellowish Wood Tiger Moth that we had seen conspicuous among the heather as we climbed the hill. For the spider's cocoon is made by the mother-spider as a silken bag for her eggs and her young ones, whereas the cocoons which caterpillars make are like sleeping-sacks, within which they pass through the great change that turns them into butterflies or moths. The mother-spider is very careful of her silk bag with its precious contents. If you try to take it away, she resists; if you take it away, she searches for it. Most spiders are very shortsighted, and it seems to be by smell that she ferrets about for her lost treasure. She may be deceived, for a little while at least, by a pith-ball of suitable size which has been rubbed against the cocoon. She is a very devoted mother, though gossips say she is a rather cross wife. There is another spider here (*Epeira cornuta*) that fixes its large cocoon to the heather by means of a loose web of threads and keeps guard over it, or, strictly speaking, under it. We also found that morning a very interesting, somewhat roughly made horizontal sheet on which very young spiders were running about. When we jostled it the little creatures huddled together in a heap. When we touched the heap the constituents promptly dropped down among the heather.

As we were idly peeling off some short moss from a boulder within reach we disclosed three or four chalky-white insects which would hardly move at all, though they waved their legs in a lazy sort of way when we turned them upside down. The biggest of them was about half the size of a threepenny bit, and it had behind it a quaint shovel-like trailer, also bright white. We were so curious that we put the little creatures into a tube and took them home. We afterwards saw babies come out of the trailer, but we never found time to learn much about them. Some day we should like to find them again and make their acquaintance better. Their learned name is *Orthezia*, and they belong to the Order Hemiptera. We do not fancy that their life is wildly exciting, but creatures that have got hold of the idea of a perambulator with the babies in it are worth knowing.

By the side of the track we were following the sheep had here and there rubbed hollows in the slope, and in the loose, well-drained soil above these places for cud-chewing and shelter we saw tufts of the Rock Rose (*Helianthemum vulgare*) with the delicate yellow flowers fully expanded in the bright sunshine. When a cloud comes overhead or when there is a fall of temperature the blossoms close up. When the sun shines they move their heads towards it. If one peers into the flower in the sunshine one sees that there are numerous stamens rather crowded together round the central pistil; and if one touches them with the tip of one's little finger they all spread out towards the circumference. It gives us peculiar pleasure to do this to flower after flower, and we must ask, Why? Perhaps, if we know the story, it is because there is a *fitness* in the outward movement of the stamens. The movement takes place in natural conditions when the appropriate insect visitor settles down on the flower—which, by the way, has no nectar. The movement of the stamens secures the dusting of the visitor's body with pollen. Therefore, when another Rock Rose flower is visited, the stigma is likely to have pollen landed upon it; and this secures the fertilisation (or pollination) which makes the possible seeds or ovules into real seeds containing embryo plants. The egg-cell inside the ovule is fertilised and launched on the voyage of life when the nucleus of the pollen-grain, carried downwards by the growth of the pollen-tube, joins forces with it. Thus the movement of the stamens helps to bring about a very important result.

But, even if we do not know this story of pollen-dusting, there is pleasure in pulling the trigger of the Rock Rose's stamens; and we fancy that the reason is that we do not expect much movement in plants and are delighted when we see it. For it brings the plant nearer us; it is a touch of nature making the world kin. An *inward* movement of stamens, towards the pistil, is seen in the hedgerow Barberry or in its garden relative Mahonia, when we touch the inner side of their bases with a bristle. It would be interesting to know quite precisely why the movement is outwards in the one case and inwards in the other.

Everyone knows that plants are very active internally, for during the day they are continually transforming the energy of the sunlight into the energy that there is in the starch, sugar, and more complex carbon compounds which the green leaf makes. In a sense they are very active internally in manufacturing the explosives that animals fire off, the fuel that animals burn, the wealth that animals spend, the food that animals eat. Not that they work for animals—they work for themselves; but they work so hard that there is plenty to spare. The question arises, however, in the mind, why plants that have so much reserve power (or potential energy) in the form of foodstuffs should not use more of it in free movement. One does not, perhaps, expect them to prowl about; but one knows how Sundews move their tentacles and Fly-Traps their leaf-blades, how the leaflets and leaves of the Sensitive Plant move when one touches them, how the tips of seedlings bend and bow in a leisurely way to the different points of the compass, how roots in an earthworm's burrow move like shoots, how tendrils coil round their support, and one asks again, why plants should move so little.

The day is young yet, and this is a pleasant bank, so we may give the three answers that we know. (1) First, there is a great deal more movement about the young and growing parts of plants than most people think. (2) In the second place, except as regards carbonic acid gas, plants are not able to get rid of their waste products as animals do, and we feel sure that this must mean a serious handicapping of activity. Plants are like smouldering fires, in some danger of being smothered in their own ashes. (3) But, thirdly, the living unit or cell of the plant is shut up in a protective wall of cellulose, which seriously hinders mobility. It is a fact, we believe, that almost all the movements of parts of plants are due to change in the turgor or water-pressure of the cells. As Professor F. O. Bower has said in his fine "Botany of the Living Plant" (1919), "Like the mediæval knight, the movements of the plant protoplast are checked by its protective armour. The plant has sacrificed mobility for mechanical defence." But it is very useful for us to look at movements like those of the Sensitive Plant, the Fly-Trap, the coiling tendrils of the Pea, and the Rock Rose's stamens, to feel that there is a good deal of the animal about some plants, just as there is a good deal of the plant about some animals. The brilliant Indian experimenter, Sir J. C. Bose, has shown of recent years that there is much in common between a message passing along a nerve in our arm and a message travelling along the leaf of the Sensitive Plant; that plants, like animals, may have their susceptibility changed by poisoning, by anæsthetics, by fatigue, and by outside circumstances; and that they are refreshed by food and rest.

As we got above the thick heather and on to the rough ground covered with granite boulders and loose stones, with Bearberry and Crowberry here and there, we skirted the edge of a corrie and looking down saw about a dozen Stags. They were to windward of us and below, so we were able to enjoy the sight. They had not begun to get passionate nor to fight among themselves, and we could see that the antlers were rough with "velvet"—the name given to the skin that covers and feeds the antlers as long as they are growing. It is an extraordinary thing this expensive annual growth of bone, which serves for a short time as a weapon and then falls off.

We sat down by a big boulder of pink granite to watch the Stags, and we could not help noticing how much fine-grained gravel had gradually gathered—clean, hard, small-bore gravel, which it was a pleasure to handle. All this had come out of the boulder, which yet seemed hardness itself. What had done the crushing? How had the crumbling come about? This is a very important question, for there is no doubt that there is a continuous slow wearing down of the mountains, and that the hills flow down into the sea. In a case like this boulder of pink granite, there had been (1) some chemical action on the part of the rain and mist bathing the surface for hundreds of thousands of years; (2) here and there lichens had been eating into the rock and making almost microscopic tunnels; (3) into the little cracks and crevices and passages the water had penetrated, and when this water froze small pieces of granite were burst off. Lying on the ground these became smaller still.

We got a good view from the top—mountains and valleys, lochs large and small, forests and farmland, the streams joining the river, and in the distance the sea. The exercise is its own reward; there is a pleasurable excitement; it is all very beautiful; and there is something like discovery in getting a sort of bird's-eye view of the district, in seeing the connectedness and relatedness of the different parts of the scenery in a way altogether different from what is possible by any amount of walking on low ground. We wonder, however, if the biggest reward is not that we get back to one of the primal impressions of our forefathers, which we are a little apt for lack of adventurousness to lose, the feeling of spaciousness and immensity—a feeling akin to that which we get in observing the star-strewn sky. But it is evidently time that we were getting down the hill.

But let us be patient for a little. This is a central and commanding height, though very accessible—else we should not be here. On such mountain-tops it is always useful to look about for traces indicating that man has used it for some purpose. Some hills we know have a vitrified fort on the top, where intense heat has been used to melt some parts of the stones;

others have a cairn commemorating some historic event; others show the residues of bonfires; others, again, have strange cup-marked stones going back into very remote antiquity; others bear the marks of the industry of the Ordnance Survey map-makers. In two or three places in Scotland there is a flat stone with two human footprints carefully carved on it, depressed for about a quarter of an inch. A learned naturalist in Inverness was fortunate enough to find one of these, and it may be seen in the museum there—a great treasure. For it seems that when the old chief died, the young chief was conducted to the stone to receive the promises of fealty, and to pledge himself to do justly. He placed his feet in the two prints and took the oaths. But, to tell the truth, we cannot find anything on this hilltop. The view is good, the air is good, but we discover no trace of previous human visitors.

In the Far North, beyond the last stunted trees but before the region covered with ice, there is the Tundra, or Barren Desert. Part of it is covered with mosses, but part of it is covered with encrusting lichens, such as are seen on the rocks on the summit of this hill. It is a good exercise to try to find in this country the counterpart of the vegetations of other countries, finding desert vegetation, for instance, among the sand-dunes, and seeing in our moorland a relic of the Great Heath of Northern Europe. Now, the top of this hill with its lichen-encrusted rocks is, if we could flatten it a bit, a picture of the Lichen-tundra of the Arctic. But what are these lichens?

Lichens are double plants, or partner plants, consisting (1) of a green plant or Alga, like the simple green dust that spreads on tree-stems in damp weather, and (2) of a colourless plant or Fungus, like many a mould. The Fungus part supplies the water and soluble salts from the rocks; the Alga part is able to build up organic compounds with the help of the sunshine. Thus the two partners work into one another's hands. This is what is called *symbiosis*—a mutually beneficial internal partnership between two living creatures of quite different kinds. The Alga partner can be got to live away from its Fungus partner, but the Fungus can very rarely do without the Algæ. The master can seldom live without his green slaves. One of the discoverers of this partnership, Professor Schwendener, wrote: "As the result of my researches, all these growths (lichens) are not simple plants, not individuals in the ordinary sense of the word; they are rather colonies consisting of hundreds and thousands of individuals, among which, however, one predominates, while the rest in perpetual captivity prepare the nutriment for themselves and their master. This master is a fungus, a parasite which is accustomed to live upon others' work; its slaves are green Algæ, which it has sought out, or indeed caught hold of and compelled into its service. It surrounds them, as a spider its prey, with a fibrous net of narrow meshes, which is gradually converted into an impenetrable covering; but while the spider sucks its prey and leaves it dead, the Fungus incites the Algæ found in its net to more rapid activity—indeed, to more vigorous increase."

It is very interesting to know that some lichens can be made artificially, by taking a known Alga and sowing a known Fungus upon it. A known lichen may result. In lichens it is the Fungus that forms the fruiting body, but the Alga enters into the partnership almost from the very first. In wet weather the surface of the lichen is often covered with a mealy powder that appears from within. The powder consists of minute contributions from both partners and it represents a vegetative way of multiplying, for it gets carried about by the wind.

As we look about we see several different kinds of lichens, and it is interesting to make a collection in a box. Some are flat encrustations, some are leaf-like, some are hairy, and so on; many are finely coloured. It seems a far cry from the top of a mountain to the chemical laboratory, but the litmus-paper that is so much used because it changes colour on the presence of any acid is made from lichens. The Reindeer Moss (*Cladonia rangiferina*), on which reindeer largely depend, and the Iceland Moss (*Cetraria islandica*), which is used for making a delicate invalid's food, are both lichens and not uncommon on British mountains. How many interests intersect even in the lichens of this hilltop!

We must not stay, but there are two interesting points which we cannot miss—that lichens begin in many cases the process of soil-making, and that, though they are very resistant to extremes of cold and heat, they are very sensitive to impurities in the air. They are creatures of the clean open air. Along with the lichens on the mountain-top there are some hardy mosses, notably the woolly Fringe Moss (*Rhacomitrium lanuginosum*), which sometimes spread like a carpet and form the beginning of moss peat at high altitudes.

Before we begin the descent, let us look downwards and distinguish the various zones. They differ a little from hill to hill, but what do we see here? (*a*) There is the barren zone at the top, with its lichens and just a few little plants eking out a sparse subsistence. (*b*) Then there is a zone that one might compare to a big rockery. There is no heather to speak of, but there are pockets among the rocks and stones where a little lichen-made soil has gathered. In some of these there are alpine plants, like the alpine Lady's Mantle (*Alchemilla alpina*), with a good deal of silky hair except on the upper surface of the leaves, and on drier places there are the creeping stems of the Club Moss (*Lycopodium selago*), a relic of an ancient vegetation. We may call this the Arctic-alpine zone. (*c*) Below this is the heather zone, or high moor, with poor, shallow soil. We must afterwards try to understand how the heather thrives so well where only a few other plants can grow. On flat water-logged parts of this zone there are peat bogs. (*d*) Towards the lower part of the heather zone we may distinguish the hill pasture. There is still some heather, but the accumulation of more soil and the existence of drainage have allowed the growth of grass, and here we see sheep. (*e*) This passes imperceptibly into the alluvial land of the valley, where there are meadows and ploughed fields. It must be clearly understood that this view of zones is only a sort of bird's-eye view. The matter is far too complicated and subtle for our simple studies here. Dr. W. G. Smith's admirable account of Arctic-Alpine vegetation in Tansley's "Types of British Vegetation" (1911) should be consulted by those who wish to go deeper and farther.

We wish to say just a little about the second zone that reminds us of a rock garden. In nooks and on ledges, as well as in the corries, there are plants like the white-flowered Snow Saxifrage (*Saxifraga nivalis*), the alpine Forget-me-Not, the Moss Campion, the alpine Flea-Bane (*Erigeron alpestris*), the Rocky Speedwell (*Veronica saxatilis*), the tufted Sandwort (*Arenaria hirta*), and the Dwarf Willow (*Salix reticulata*).

We have compared the lichens on the summit of the hill to the Tundra of the Far North, and there is a distinct suggestion of the Arctic flora in these "alpines" of a Scottish mountain. Some of them have near relatives in Arctic regions, and others show adaptations similar to those which are seen in Arctic plants. It must be remembered that the conditions of life have no little severity in the high levels of some of the greater mountains of Britain. On Midsummer Day we have seen snow still lying in a cup on the Lammermuirs, which are neither high hills nor very far north (between East Lothian and Berwickshire). Many a year, we believe, the snow of the previous winter has not *quite* gone from the Cairngorms before that of the next winter begins to fall.

Most of the alpine flowering plants, like those of Arctic regions, are *perennials*, lasting on as individuals from year to year. One reason for this is that the growing season is too short to allow of germination, flowering, fruiting, and seed-scattering being completed in one period, as is the case with annuals. A second general feature is that the "alpines" are adapted in one way or another to reducing the loss of water by transpiration. But we shall return to the adaptations or fitnesses of mountain plants in our third study.

Near the top of the hill there were several flourishing tufts of Thrift, or Sea Pink (*Armeria vulgaris*), which one is accustomed to find on rocky places near the shore. It is striking to find a seashore plant on the top of a mountain. It is adapted for hard conditions—a perennial with narrow leaves from which the loss of water is strictly economised. Its fine rose-pink tufts of flowers are very conspicuous, but there are not many insects to attract up here, and, as a matter of fact, the Thrift is able to dispense with their visits. The styles of the flower have a way of coiling that ensures their being dusted with pollen from the stamens. Self-pollination will occur if insect pollination fails.

It is not very clear why the Thrift should be found in the extreme situations of mountain-top and seashore rocks, and not (unless as a rarity) in the intermediate zones. The same is true of the purple-flowered, opposite-leaved Saxifrage (*Saxifraga oppositifolia*), which occurs only above 3,500 feet and at sea-level. It has been suggested to me that both plants flourished between the two extremes before the severe glaciation of the Ice Ages, that the ice gave place to vast tracts of forest and moor over the greater part of the country, and that the Thrift is constitutionally unsuited to living in either of these habitats. Nowadays it is probably isolated on the hilltops by the moor cordon and on the shore rocks by the surrounding zone of cultivation.

It is interesting to notice that on a particular stretch of rocky ground at no great altitude, a succession of vegetations may sometimes be demonstrated: (1) Closely encrusting lichens and some very simple green Algæ; (2) more bushy lichens like Reindeer Moss; (3) communities of mosses; (4) some hardy flowering plants in suitable pockets; and (5) the heather. So that the zones we notice on looking down the hill correspond to phases which may appear in succession on a particular area.

We occupied ourselves on the way home in collecting, in our mind at least, things that were particularly interesting, though, of a truth, in wild nature we do not know what an uninteresting thing is. Let us mention a dozen of our finds. The bleached skull of a Curlew with its long, curved bill, well suited for probing, and we remembered that it is neither long nor curved in the very young bird, else there would be difficulties in regard to the egg! The shells of very minute snails fastened to the heather; they must be food for many a hill bird, such as the Wheatear. A piece of a Red Deer's antlers all gnawed away; the deer eat them gradually after they fall off, an economical thing to do. A circle of small feathers where a Hawk had plucked a small bird and the skull of a Hare with the hind part slipping off from the rest. These are among the many hints of the reality of the struggle for existence on the hill.

Hung on the heather was the nest of a wasp (*Vespa sylvestris*), about the size of a tangerine orange—a paper house made from chewed wood, a suspended house with several stories, a waterproof house full of babies, truly a wonder. Many little moths were flitting about, such as the common Heath Moth (*Ematurga atomaria*), and there were some cocoons. Another find was the slough of an adder—the outermost layer of the epidermis cast off in a piece, and turned inside out. It is interesting to see the imprint of all the scales, for it is hardly necessary to say that the scales are not sloughed, including the mark of the transparent blind over the eye. We were pleased to see a Brown Lizard (*Lacerta vivipara*) very high up and an astonishingly red Frog lower down. Both were after the same things—the insects of the hill.

The beautiful little Milkwort (*Polygala serpyllacea*) was much in evidence, and we saw the three different colour varieties—blue, pink, and white. We were glad to find a clump of the Needle Furze or Petty Broom (*Genista anglica*) in flower, a dwarf and spiny second cousin of the Common Broom (*Cytisus scoparius*). Lower down among the Bog Moss we found Butterwort and Sundew, which we shall speak of later, and in the beginning of the pasture land the dominant plant, apart from the grass, was the beautiful Eyebright (*Euphrasia officinalis*)—a bit of a hypocrite, as we shall see, in spite of its look of innocence, for it is not entirely depending on its own resources. We got "oak-apples" on a young oak-tree, and a strange hairy growth on a brier rose near the foot of the hill. Gall-insects belonging to the Order of ants, bees, and wasps (Hymenoptera) lay their eggs in the soft tissues of plants, and the juice from the mouth of the developing grubs seems to incite the plants to form a gall. But the puzzle is that on a particular plant a particular insect produces one kind of gall and no other, and that it is usually just as perfectly finished as if it were a normal growth. On a birch-tree we got the empty cocoons of a very handsome Sawfly (*Trichiosoma* *lucorum*), and on the branches there were the strange growths called Witches' Brooms. These are produced by the irritation of a Fungus (*Exoascus*), which provokes a prodigious development of slender twigs, often suggestive of a crow's nest. But now we are on the road, and there is nothing for it but tramping and thinking and watching the bats till we get home.

CHAPTER II

THE MAKING OF MOUNTAINS

Mountains and mountains—Volcanic mountains—Moraines—Fold mountains—Dislocation mountains—Carved-out mountains.

It does not seem practicable to make any clear distinction between mountains and hills. For though we think of mountains as higher and altogether bigger and grander than hills, the quality of size is not one to which we can attach great importance. What is important is to try to understand how there have come to be hills and valleys, mountains and plains, and all in such pleasing diversity.

Geologists, such as the late Professor James Geikie, in his "Mountains: Their Origin, Growth, and Decay," tell us that there are two great kinds of mountains: (1) Original, or Tectonic; and (2) Subsequent, or Relict. In the former class we include every height which owes its origin either to (i) *the piling or heaping of materials at the surface;* or to (ii) *subterranean action which has resulted in the folding and rupturing of the earth's crust.* Subsequent or Relict mountains have originated in quite another way. They have neither been built up by accumulation at the surface, nor are they due to crustal deformation. On the contrary, they are *the residual or remaining portions of former high land,* mere relics or fragments of more or less elevated tracts which have been gradually reduced in extent, and largely subdued by the forces of decay. Mountains of the second class are the remains of plateaus or raised blocks of the earth's crust which have been eaten away unequally by frost and rain and other "weathering" agencies. But mountains of the first class are elevations produced by uplifts and crumplings of the earth's crust or by volcanic eruptions. This will become clearer after we have considered the different kinds in more detail.

From a hole broken in the earth's crust there may be an eruption of molten rock or lava, and the accumulation of this, along with slags, cinders, rock fragments, and dust may form Accumulation mountains of *the volcanic type*. A simple volcano may form a conical mountain with a central pit or crater above the mouth, and this may eventually become a crater lake. When the looser materials are swept away the throat of the old volcano, choked with solidified hard rock, may be left as a central core or boss. Sometimes, to take a very different case, the vents of the volcano may have belched out floods of lava, burying a wide range of country and forming lava plains and lava plateaus. There are many different kinds of volcanic mountains, but they do not concern us at present. All we need just now is a clear picture of one of the ways in which mountains are formed, and it should be noted that this kind of mountain-making is still being illustrated around more or less active volcanoes like Vesuvius and the lofty Mauna Loa in Hawaii.

As examples of volcanic mountains we may name: Fuji-Yama, in Japan, Cotopaxi in Ecuador, Popocatepetl in Mexico, the Peak of Teneriffe, the cone of

Palma in the Canaries, and the Puy-de-Dôme in Auvergne.

On the enormous heaps of débris which disfigure the vicinity of smelting works, and better still in the accumulations of rock dust around gold mines, one may see the making of miniature gorges and valleys under the influence of rain, frost, wind, and other weathering agencies. The same sort of thing on a large scale is going on around still active volcanoes, but what is worn away and carried away is made good again by fresh eruptions. When the volcano has been long extinct the weathering has had time to tell, and it may go so far that the volcanic nature of the mountain is no longer very obvious. "In many cases," Professor Geikie writes, "the cone-like form still persists, although profoundly furrowed by innumerable gullies and gorges; in other cases the original symmetry has entirely disappeared; while in yet others only a few low hills, or merely a single abrupt knoll, may be left to mark the site of a formerly extensive and lofty mountain."

Mount Rainier (or Tacoma), the highest mountain in Washington State, rising to 14,444 feet, is an extinct composite volcano, which has suffered great denudation. It is now snow-capped and supports glaciers, but it is still recognisable for what it is. But many others have been worn away to their very roots. Not infrequently there remains the plug of igneous rock that solidified and choked the old neck or funnel of eruption, and this stands out as a boss or tower—a conspicuous feature in the landscape. There are many of these "necks" in Scotland, vestiges of very ancient (Palæozoic) volcanoes, such as Arthur's Seat near

Edinburgh, North Berwick Law, and the Binn at Burntisland. According to the nature of the rock filling the "neck" will be the final result of the weathering, for it may result in a precipitous crag like the Castle Rock in Edinburgh, or in a rounded grass-covered hill like Largo Law in Fife. But perhaps we have said enough about the first kind of Original mountain—the *volcanic* type.

Along with volcanic mountains may be grouped *glacial hills*, which are due to the accumulations of rocky débris showered by mountains on to the surface of glaciers and carried down to form moraines. When the glaciers retreat or disappear the moraines are left as dumped ridges of rock rubbish and gravel, which are sometimes almost mountainous. Hummocky moraines, often forming parallel ridges, are very common in the Scotch Highlands and throughout the countries—*e.g.*, Prussia and Denmark—dominated by the gigantic glacier which once filled the basin of the Baltic. As Professor Geikie has it, "The terminal moraines of that enormous glacier are conspicuous in all these lands, where they acquire an importance which they could not have in a country of bolder relief. They constitute, indeed, the most extensive *paysage morainique* of Europe—a broad region crowded with innumerable winding and interosculating ranges of hummocky ramparts and ridges, and vast assemblages of rounded conical knolls, mounds, and hills, the hollows amongst which hold lakes and lakelets, bogs and morasses innumerable." It may be mentioned that "bottom moraines," formed underneath the glaciers as the result of grinding form "drums" or "drumlins," which are abundantly illustrated in Ireland, and that long winding ridges or embankments of gravel called "eskers," very characteristic of Sweden, appear to mark the courses of ancient *sub-glacial* rivers.

The second great kind of mountain is known as *folded*, and is formed by some sort of crumpling of the earth's crust. They are also called Deformation mountains. Most of the great chains and ranges of mountains belong to this group of Folded or Fold mountains, and they differ in character according to the way in which the crumpling occurs. No one has ever seen this kind of mountain in the making, but there is evidence that some were formed all at once by one continuous and probably very slow crumpling, and that others were formed by a succession of lateral thrusts interrupted by long periods of rest. If we take a piece of thick felt, like that used for a crumb-cloth, and compress it from the sides, we can make a series of folds or ridges which mimic in a rough way simple mountain ranges, especially if the felt is saturated with water on a cold winter day and freezes hard while we hold it tight. If we press the felt unequally the folding will be more complicated; if it is not of the same texture throughout fresh complications will arise; if the felt is made of several different layers of different ages and materials there may be further intricacies in the folding; and, finally, if the crumpled, layered, and hard-frozen felt be partly thawed and then compressed very hard so that the folds break in places and under layers are thrust above upper layers, and so on, we may begin to get an idea—a far too simple idea, of course—of what has happened in the formation of complex Fold mountains like the Alps.

A mountain-range *may* be so simple that it consists just of one broad saddleback (anticline) of arched beds or strata of rock; or there may be a series of saddlebacks with troughs (synclines) between. But matters are rarely so simple as this. The folds become folded and merged with one another, they are overturned and broken, and great sheets of rock hundreds or thousands of feet thick may be thrust over younger rocks for many miles. Then, again, the results of unequal weathering may greatly disguise the original folding. It is only after much hard study that we can read the story of a mountain range for ourselves. Thus, to

DIAGRAM OF MUCH-WEATHERED SADDLEBACKS (ANTICLINES) AND TROUGHS (SYNCLINES), DUE TO FOLDING OF THE EARTH'S CRUST.

Similar strata are similarly shaded.

take a simple case, it often comes about that an original saddleback or anticline coincides with the valley of to-day and a trough or syncline with the hill. Another caution to be borne in mind is that the intense pressure which has brought about mountain-folding, as the outcome of subterranean changes, must often have produced great heat. As the result of this heat the rocks became plastic, and as another result their original composition and texture were often profoundly altered. Rocks laid down in the form of sediment—sandstone, for instance—may be changed ("metamorphosed") into crumpled and gnarled schists; limestone may be changed into marble; ancient schists and granites may be almost made over again. In short, to use the technical word, mountain-folding is associated with the *metamorphosis* of rocks.

There are other mountains known as *Dislocation or Block mountains*, which are due to the fracturing of the earth's crust and to unequal vertical subsidence. They are blocks of the crust which have maintained their relative position while adjacent tracts have broken away and subsided. Or a great piece of the earth's crust may be tilted up at one side and depressed at the other. We sometimes get a hint of the formation of Block mountains when we watch the breaking up of the ice on a thickly frozen reach of a river where the flow is very slight. Big masses sink down and others are tilted up into prominent blocks.

The greatest Dislocation mountains in the world are the long parallel ranges of the Great Basin of North America, a remarkable plateau stretching from west to east for some 500 miles between the Sierra Nevada and the Wahsatch Mountains, and extending for nearly 800 miles from north to south. On a much smaller scale are the mountains of Moab and Palestine, rising above the great down-sinking of the Jordan Valley and the Dead Sea. The Vosges and the Black Forest represent Dislocation mountains with the broad down-sinking of the Rhine Valley between them.

Another type of mountain may be included here, the elevation that is produced when the crust is bulged upwards owing to the pressure of a mass of molten rock beneath which had not force enough to form a volcano. It may be roughly compared to a swelling on pie-crust. The molten roll that bulges up the crust may intrude into the surrounding strata in the form of more or less horizontal "sheets" or "sills" or as "dykes" and "veins." Traprain Law in East Lothian, Salisbury Craigs at Edinburgh, and the Abbey Craig near Stirling are examples of exposed intrusive sheets or sills.

Not far removed are the Bosses, huge igneous masses, often granitic, which intruded into adjacent rocks, and probably cooled and consolidated at greater depths than those we have already mentioned. They may appear on the surface through the more rapid weathering away of the rocks into which they bulged. Many granite mountains in Britain belong to this Boss type, such as Goatfell in the island of Arran and the dome-like Red Hills of Skye. The very different peaked and pinnacled Coolin Hills are said to have been carved out of a great boss of the rock called "gabbro," representing an earlier intrusion than the Red Hills.

So far, then, what is clear? The crust of the earth, the lithosphere, consists of the more or less elevated, but partly submerged, "continental plateau," and a more depressed portion known as the "oceanic basin" which descends in some places into enormous "deeps." Some of these are six miles deep, so that if Mount Everest could be thrown in not a trace of it would be seen above the surface. Now the earth is still cooling and contracting, as it has been doing for many millions of years. This means that subsidence of the crust goes on, both in the continental area and in the oceanic basin and there is a good deal of evidence that the meeting-line of the two great areas is a zone of special instability, where mountains and troughs are particularly likely to be formed. The marginal tracts are especially unstable, and there "protracted spasms of mountain-making" have repeatedly occurred—mountain-making which results in the Fold mountains and Block mountains, Bosses and Volcanoes, to which we have briefly referred. It must be understood that mountain-making is one of the most difficult of subjects, and what we have said does not go very far. We hope, however, that it is true so far as it goes. It is time now to pass to those mountains which originate in a way radically different from those we have hitherto studied.

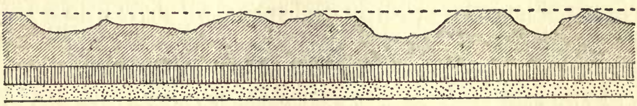

DIAGRAM OF CARVED-OUT OR RELICT MOUNTAINS.

The lower zones are undisturbed sedimentary rocks. On these rests a plateau of accumulation, originally up to the level of the dotted line, which now represents the summits of the higher mountains.

When is a mountain not a mountain? When it is the remnant of a much-weathered plateau or Block mountain. It has not been uplifted, in its present form at least; it has been carved out by weathering agencies —the rain, the frost, the glacier, the avalanche, the landslip, the torrent, the heat of the sun, the wind-blown sand, and the air itself. Such mountains are called Subsequent, Relict, or Residual, and we may almost say "Carved-out." They differ fundamentally from Original or Tectonic mountains, which we may almost call "True mountains."

As Professor Geikie says: "They have not been built up after the fashion of volcanoes, for example, neither do they owe their existence directly to deformation of the crust. On the contrary, their most characteristic representatives are remnants of formerly more or less extensive high grounds or plateaus of one kind or another. The strata with which they were once continuous have been gradually reduced and removed by surface weathering. Relict mountains are thus monuments of erosion; they have been carved out of rock masses, the geological structure of which varies indefinitely, but rarely coincides with the outline of the ground."

Let us follow Professor Geikie farther. An Original or Tectonic mountain may be eroded down to its roots, to its base-level. In this way an undulating plain—*a plain of erosion*—comes to replace the vanished mountain. If the plain is gradually uplifted again it becomes *a plateau of erosion.* Or if the plain is submerged beneath the sea and sediment accumulates upon it in the form of gravel, sand, or mud, and if the drowned and buried plain be bulged up again, it becomes a *plateau of accumulation.* If the erosion of the Original or Tectonic mountain was not so thoroughgoing as we supposed there might be (after re-elevation) a plateau of erosion with a more or less irregular surface, or a plateau of accumulation the lowest parts of which showed the irregular stumps or roots of the Original mountain, while the upper parts consisted of more or less horizontal beds of sedimentary rock.

Now the point is, that Relict or Residual mountains may be carved out of a plateau of accumulation, out of an accumulation tableland, and such mountains are very often like pyramids or like pyramids without their tops. They tend to show terraces, steps, or corbels, corresponding to the sedimentary beds. They often look like castles and fortresses, as in the picturesque sandstone of Saxon Switzerland. They are table-mountains and pyramids in the dissected plateau of the Sahara. The character of the result will vary with the character of the sedimentary rocks and with the nature of the dissecting instruments—whether warmth and cold, or rain and snow, or the wind-driven grit and sand. The dissections that have been made in the cañon region of Colorado are famous, and nearer home the basalt rocks of the Inner Hebrides and Antrim are the residues of a great plateau of accumulation. Most of the escarpment hills of Central England illustrate the carving out of plateaus with inclined strata.

But Relict mountains may also be carved out of plateaus of erosion. This is very largely the case with the mountains of the Highlands of Scotland, such as the Cairngorms. A great tableland, consisting fundamentally of the remains of very ancient Tectonic or Original ranges, has been carved into the well-known "Bens." These, as Professor Geikie points out, are very generally massive and round-shouldered, not like the peaks and "horns" of the Alps. They are usually in groups and not differing much from one another in height. "One can hardly doubt that such relationship is due to the simple fact that the mountains are the remnants of a tableland, the surface of which is indicated approximately by the summits of the several mountain-masses. If we in imagination fill up the valleys, we shall in some measure restore the general

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aspect of the Highland area when the mountains began to be shaped out by Nature's saws and chisels." It should be noted that the great Highland Plateau, which has been so wonderfully carved, is in some places a plateau of accumulation as well as of erosion.

What is true of the Scottish Highlands is true also of the Southern Uplands. Great Folded mountains, buckled up in very ancient (Palæozoic) times, have been worn down and in some cases base-levelled. Much of the plain of erosion was then submerged and loaded with sedimentary rocks, such as shales. It was then bulged up into a plateau, which, like that of the Highlands, was partly a plateau of accumulation and partly a plateau of erosion. Then followed the long carving out of the tableland into broad-topped and flat-topped hills, much tamer than the Highlands except in Galloway. It has to be remembered that the prevalent rounding of Relict mountains, in contrast to the prevalent peaking of Folded mountains, has been made more marked by severe glaciation, in Southern Uplands and in the Highlands alike.

The mountains of the Lake District, of Wales, of Ireland, of Norway and Sweden, and the elevated tracts to the north of the Pyrenees, Alps, and Carpathians are all monuments of erosion; indeed, these Relict mountains occur in most parts of the globe.

Two final cautions we venture to make. The first is that plateaus of accumulation may mingle with plateaus of erosion, and, what is more important, that it is not always easy to draw the line between the Original mountain range and the carved-out plateau. For a considerable residue of Folded mountain or Volcanic mountain may remain in the tableland that is

SUMMARY (BASED ON GEIKIE'S "MOUNTAINS").

- **MOUNTAINS**
  - I. ORIGINAL, OR TECTONIC.
    - A. Accumulation Mountains
      - Volcanic: Cones, etc.
      - Non-Volcanic:
        - Glacial Moraines, etc.
        - Sand Dunes, etc.
    - B. Deformation Mountains
      - Folded Mountains.
      - Dislocation or Block Mountains.
      - Bosses and Sills.
  - II. SUBSEQUENT, RELICT, RESIDUAL, OR CARVED OUT.
    - From Erosion Plateaus.
    - From Accumulation Plateaus.
    - From Mingled Erosion and Accumulation Plateaus.

denuded and dissected. Yet the distinction of the two kinds is in typical cases quite clear. The second caution is that it may be practically injudicious to inform the patriotic inhabitant of either the Scots Highlands or the Southern Highlands, of either the Lake District or Wales, that his mountains are not genuine or Original mountains at all, but only the outcome of the carving out of plateaus. Considerable preparation is sometimes necessary to make a scientific fact palatable.

CHAPTER III

ADAPTATIONS TO HIGH ALTITUDES

Ptarmigan—The Marmot's sleep—Canadian Ruffed Grouse—Spring Tails of the snow level—The Alpine Salamander—Some characteristics of mountain plants—Origins of British animals.

In the course of time living creatures—whether plants or animals—tend to become specially suited to the particular conditions of their life. The Whale is suited to the open sea in its shape, its smoothness, its blubber, its balancing flippers, its propelling flukes, and in a score of other ways. The Cactus is suited to the arid desert in its leaflessness, its thick skin, and its capacity for storing water. Changes crop up, and, if the conditions of life are not easy, there is discriminate sifting; thus those varieties of each kind tend to survive which are relatively fittest to particular habitats and ways of living. This is the theory of Nature's sifting or Natural Selection—a sound theory so far as it goes, but with the obvious drawback that it does not account for, or pretend to account for, the inborn changefulness which supplies the raw materials to be sifted. But while the theory is still far from complete, there is no doubt about the facts. Living creatures are bundles of adaptations. As a great naturalist once said: "Wherever you tap Organic Nature it seems to flow with purpose." And our particular question now concerns the ways in which plants and animals are suited

THE PTARMIGAN IN SUMMER
(Copyright G. Brooksbank)

THE PTARMIGAN IN WINTER
(Copyright Dr. Ritchie)

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to life at great heights. The Common Dormouse (*Muscardinus avellanarius*) is a very characteristic alpine animal, able to live at an altitude of 5,000 feet; one of its adaptations is that it is a winter-sleeper. The Chamois of Switzerland, a goat-like antelope of Asiatic origin, is a hardy and adventurous climber, and the close hair of its coat is adaptively protective against the cold.

One of the grandest walks in Scotland, and that is saying much, is from the valley of the Dee to the valley of the Spey across the Larig Pass—in other words, from Braemar to Aviemore. If we climb a little near the watershed we are sure to come across a very characteristic bird of the mountains—the Ptarmigan (*Lagopus mutus*), first cousin of the Willow Grouse and second cousin of the Red Grouse. Two of its adaptations to high altitudes are striking. It is peculiar among birds in moulting three times in the year, having a somewhat grouse-like spring dress, a greyish summer dress, and a white winter dress. The winter plumage is snowy white except for a few black feathers in the tail and a black bar in front of the eye, and this whiteness gives the bird a garment of invisibility among the snow. Sometimes among the snow one almost puts one's foot on a crouching Ptarmigan. Moreover, for a creature with a high body temperature living in very cold surroundings there is no more economical dress for preserving the animal heat than a suit of white feathers or white fur. The same fitness or adaptation is seen in the Mountain Hare which turns from yellowish grey to white all but the tips of its ears and in the reddish-brown Stoat which turns into the Ermine, all white save the tip of its tail. We have spoken of these in another part of this book. The Arctic Fox (*Canis lagopus*) and the Collared Lemming (*Cuniculus torquatus*) may be noted as two other examples of turning white in winter. Permanent whiteness is characteristic of many northern animals, such as Polar Bear, American Polar Hare, Greenland Falcon, and Snowy Owl. It is plain that what suits well for the Far North is likely to suit also for high altitudes.

We have called the whiteness of the winter Ptarmigan a garment of invisibility, but it is not to be supposed that this protection is perfect. Very few of these fitnesses are. We remember, for instance, the fact that the Snowy Owl (*Nyctea scandica*), a native of the barren grounds of the Far North both in Europe and America, and an occasional visitor to Britain in very cold winters, will pick up snow birds like the Ptarmigan and snow mammals like the Mountain Hare. Its own plumage is white with variable dark spots and bars, and it has a strong silent flight. It hunts by day, wary but fearless, master of its fate and defiant of difficulties.

The other adaptation of the Ptarmigan to high altitudes is to be found in its heart. It is well known that going up a mountain is very trying to people with a weak heart, and that is seen even when they ascend in a rack-and-pinion railway. The reason is that at a great height the air is rarer, there is less oxygen to be got out of a breath. One way of meeting the difficulty is to take big breaths at rapid intervals, but this panting is very exhausting. Another way is to get the heart to beat more quickly so that more blood than usual is sent to the lungs every minute. But this also is exhausting. Now it is very interesting to compare the heart of the Ptarmigan from high altitudes with that of the Willow Grouse from low levels and to find that the heart of the Ptarmigan is specially strong.

Everyone who has climbed a little in the Alps has heard the shrill whistle of the Marmot (*Arctomys marmotta*)—a danger signal that is followed by instantaneous disappearance. The animal is about the size of a wild rabbit, greyish yellow and brown in colour, and of sociable disposition. It is a rodent and a vegetarian. When winter comes on the Marmots retire in companies of a dozen or more to their burrow, which has been previously stocked with dried grass. This is largely for bedding and blankets, for survival depends on keeping up a certain degree of warmth in the retreat, but it may also serve to some extent as provender. The Marmot's adaptation to the mountains is to sink into winter sleep, and this deserves our study.

Birds and Mammals are alone among living creatures in being "warmblooded," which means that they are able to preserve an almost constant body temperature year in, year out. In an intricate way, which we cannot explain shortly, they are able to adjust the production of animal heat within their bodies to the loss of heat by the skin. In other backboned animals—namely, Reptiles, Amphibians, and Fishes—there is no such power, and the body temperature tends to approximate to that of the outside world. This is what is meant by "coldblooded." When the outside temperature is too low for a continuance of the ordinary vital processes, these coldblooded creatures sink into a winter lethargy, and they are able to endure a much lower body temperature than is possible for Birds or Mammals. But if the outside temperature falls below a certain limit—in most cases an uncertain limit—they die. It is plain that these coldblooded animals have not attained to that mastery of life which we see in a Chamois, which seems to be quite comfortable on the Alps about the line of perpetual snow.

But all Mammals are not equally perfect in their constitutional arrangements for "warmbloodedness." This is very marked, for instance, in the three lowest Mammals which lay eggs, the Duckmole and the two Spiny Ant-eaters of Australia; and the same imperfection is seen in some other cases. Now it seems clear that hibernating Mammals are those which have circumvented this imperfection, and have made a strength out of a weakness. The Bat and the Hedgehog, the Marmot and the Dormouse, are imperfectly warmblooded—just like nestling birds—but they have found a way out. When the winter approaches they do not attempt the impossible, but sink into a state of inactivity *within a confined space*, to the temperature of which their body temperature tends to approximate. If they fell asleep in the open, they would certainly be frozen to death; in a snug hole or sheltered nook the coma is more or less safe. But if the sleeping-berth become very cold, and the sleeper does not awaken in time, he passes from sleep into death. Yet there is more than getting into a snug hole: there is the practical cessation of activities. There is rigid vital economy, just enough burning away of stored fat and the like to compensate for the inevitable slight loss. What a strange state it is, with no income and almost no expenditure! The heart beats slowly and very feebly, breathing has practically stopped, and the kidneys do not function. There is no sleep so near to death as the winter sleep of the Hedgehog. But it is usually a success.

It may be that the comparative warmth of the sleeping-berth, which several inmates sometimes share, and the closeness of the atmosphere help to keep the sleeper sleepy, and that an accumulation of inevitable waste products in the body brings about a sort of drugging; but we have to remember that the winter sleeping is not an individual experiment—it is part of the racial constitution and has been slowly wrought out in the course of ages. It has been engrained in the constitution—this habit of hibernation; it is an internal rhythm, which normally corresponds to the external periodicity of the seasons, but does not necessarily do so. Thus Woodchucks may go to bed while the weather on the Adirondacks is still warm and pleasant, and unusually severe cold may *waken* a hibernator. Indeed, there is a good deal of truth in the hard saying of an old investigator of the puzzle of hibernation, that winter sleep is not sleep, and that it has nothing to do with winter. It must be noted that we cannot draw any distinction between the summer sleep of the Tenrec of Madagascar and the winter sleep of the European Hedgehog.

The winter sleepers differ considerably in the soundness of their slumbers. The sleeping Hedgehog may be immersed in water for twenty minutes or subjected to noxious gases and yet remain asleep, and the Marmot of the Alps is another heavy sleeper. The Dormouse, on the other hand, is a rather light sleeper;

and many Bats waken when there is a spell of fine weather in midwinter.

If it be asked why a Hedgehog hibernates, while a Mole does not, part of the answer is that the Mole is a burrower who finds earthworms and grubs beneath the reach of the frost's fingers even in midwinter. If it be asked why Bats hibernate, while Birds do not, part of the answer is that the great majority of Birds in North Temperate regions evade the winter by migrating. If it be asked why Brown Bears hibernate, when Stoats do not, part of the answer is in the fact that the Brown Stoat becomes in winter the White Ermine, and that the white robe makes the problem of facing the cold much easier. If it be asked why the Jerboas of the Kirghiz steppes hibernate, while the Squirrels in the forests farther north remain wakeful, part of the answer is that the Squirrels accumulate stores of food for hard times. Generalising all this, we may say that the Mammals which do not hibernate have in many cases some special adaptation or fitness that enables them to cope with the winter, or, if they have none, that they have hardy resistant constitutions, as in Wolves and Foxes. But there is another half of the answer.

Mammals are descended from coldblooded Reptiles, and some are less perfectly warmblooded than others. Those that have some imperfection in their heat-regulating arrangements, remaining in this respect young or old-fashioned, have made a virtue of necessity by becoming hibernators. When great cold sets in outside, they cannot sustain their body temperature at the level required for a continuance of everyday activities, so they relapse into a life-saving coldbloodedness and inactivity. They pass into a state in which they can fast without feeling the worse for it; they lie low with dulled sensitiveness instead of fretting themselves to death in a hopeless struggle with the cold scarcity. But we must not think of individuals trying to do this, or, as it were, stumbling into doing this; we are face to face with a slowly wrought-out adaptation which has been a success. Certain constitutions, handicapped by a certain imperfection, have survived because of their ability to sink back into inaction and a certain amount of coldbloodedness, and because of their innate shrewdness in seeking out sheltered sleeping-berths. In our "Biology of the Seasons" we have discussed this interesting problem in detail.

But we cannot leave the sleeping Marmot, a typical Mammal of the mountains, without noting that, apart from evading the severity of the winter, the hibernation pays in giving the creature a long rest—a rest even from eating. This long rest, like a very long sleep to an overworked man, gives a chance to processes of rejuvenescence to stave off that senescence which is the universal and apparently inevitable tax on structural complexity.

Birds do not hibernate, partly because their warm-bloodedness is so perfect, partly because their feathers fit so closely, and partly because those that "feel the cold" evade the winter by migration. There is no doubt that some of our resident mountain birds, like the Red Grouse, come lower down in winter; and the Curlews leave the snow-covered moorland for the low-lying fields and the seashore. We sometimes see half a hundred Curlews at a time working among the jetsam strewn on the beach.

But although Birds do not hibernate, there are a few interesting cases of lying low for a short time. Thus the Canadian Ruffed Grouse (*Bondsa umbellatus*) plunges into the soft snow of drifts and makes a passage about two feet long with an enlargement at the end. The loose dry snow serves as a non-conducting garment, just as it does for the bulbs and roots of plants, and the Ruffed Grouse may lie *perdu* for several days—warm beneath the snow.

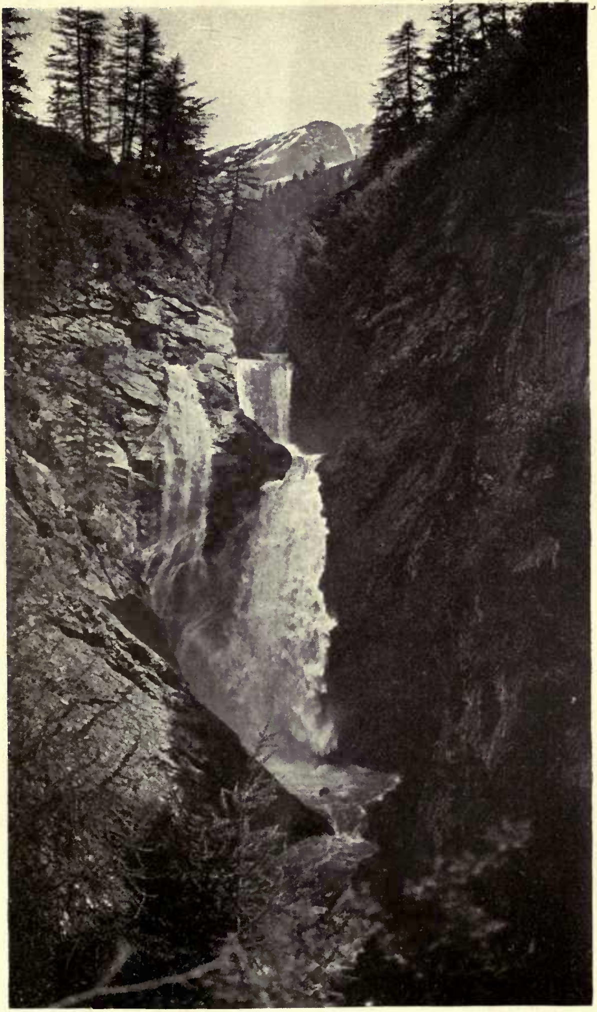
The same bird shows in winter a very neat adaptation for walking on the surface of the loose snow without sinking in. It puts on "snow shoes," in the form of hard skin plates on each side of each toe, reminding one a little of the scalloped margins of the toes in a Grebe. The area of the foot is doubled by this simple device, which spreads the bird's weight over a larger surface.

We are often impressed with the delicacy of living creatures. These beautiful transparent Ctenophores, or Comb-Bearers of the open sea, they sink to quiet depths whenever the "white horses" begin to prance on the surface. We have known of two hundred birds being found dead in a small stackyard after a very cold night when the temperature fell just a little below the bird's limit of warmbloodedness. A slight knock on the head kills the strong Mole forthwith. But at other times we are impressed with the toughness of life. Let us give an example.

No place could be more inhospitable than the surface of a glacier, unless it were an iceberg. Yet on the glacier there are often great multitudes of so-called "glacier fleas"—not really fleas, of course, but old-fashioned, primitive, wingless insects, known as

Spring Tails. They have a curious spring bent forwards beneath the body from near the tail end, and when this is released at a critical moment they jump into the air. On a stretch of the *mer de glace* at Chamonix a naturalist saw not long ago an army of "glacier fleas" (*Desoria nivalis*) over twenty yards broad by over a mile long. He estimated the number at about forty millions. On another occasion in Carinthia the surface of the snow was black for half a mile with a marching army of Spring Tails. It is not very clear what these mass movements of tiny insects mean. There are places specially suitable for laying the eggs, and when the young insects are hatched they disperse in great bands in search of food. There are also places where they lie low through the winter, and from which they migrate in spring. In other cases, perhaps, the march of the tiny insects may be simply a trekking in search of food and more comfortable quarters. We wonder that they subsist at all, for Spring Tails (Collembola) and some of their relatives the Bristle-Tails (Thysanura) are found high up the mountains in most inclement situations. Life is truly insurgent and indomitable. Over thirty different kinds of Spring Tails are known from the snow-level of the Central Alps. They feed on decaying plant remains, on Lichens encrusting the rocks, and on the showers of pollen that the wind sometimes blows up from the pine forests. What they most avoid is drought. For a coldblooded animal among the snow, black is physiologically the best colour, and most of these little insects are very dark. Perhaps the hairs on their body are also of some protection against the cold. But there is another defence, which few of us would have thought of—namely, their minuteness. There are physical reasons why the minuteness of the body—they are not bigger than one of these letters—prevents the freezing of the blood. It is a quaint idea, finding safety in being not merely a pigmy, but a Lilliputian.

There is a small Newt (*Triton alpestris*) which ascends the Alps to between 6,000 and 7,000 feet; but it shows no special fitness for mountains, and it occurs also on low ground in the Netherlands. It is otherwise with the Alpine Salamander (*Salamandra atra*) which is restricted to the heights of the European Alps, from 2,000 to 9,000 feet. It prefers to live within reach of the spray of a waterfall or in places where there is damp moss. One of its special adaptations is that it produces only two young ones at a time, whereas its near relative the Spotted Salamander produces from fifteen to fifty. Moreover, the young of the Alpine Salamander are fully developed before they leave the mother, whereas the young of the Common Salamander have to pass through some noteworthy changes after they burst from the just-laid eggs. The unborn young of the Alpine Salamander have three pairs of long red gills, which are pressed against the wall of the mother's oviduct so that an exchange of gas is effected between the blood of the offspring and the blood of the mother. But more than that: the gills are used for absorbing yolk material furnished by other eggs which do not come to anything. These peculiarities must be connected with the fact that the Alpine Salamander lives at altitudes where there are few waterpools suitable for the larvæ to swim in. The number of young has been greatly reduced, but they



WATERFALL AT VALSOREY, SWITZERLAND

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are born at a well-advanced state. This case illustrates in an interesting way how the life histories of animals differ from one another by the lengthening or the shortening of particular chapters. In the Alpine Salamander all the free-swimming or juvenile larval period has been, as it were, telescoped. It has been shunted back into the antenatal period within the mother.

Mountain light is of greater intensity than lowland light. But light retards the growth of green plants. Perhaps this is part of the explanation of the dwarfness and sparse foliage of flowering plants on high mountains. Their stems are short and their leaves are small. Many alpine plants tend to grow like squat cushions. Professor Schimper points out, in his great "Plant Geography," that "the great intensity of light causes the stronger development of certain pigments, especially of anthocyan, in flowers and foliage, whilst on the other hand it causes a more rapid decomposition of the chlorophyll. The richness of mountain light in ultra-violet rays probably favours the development of flowers." Perhaps this is part of the explanation of the large number of flowers and of the intensity of colouring in many alpine plants. Some flowers that are white in the lowlands become brightly coloured in experimental gardens at high altitudes. This is the case with the White Clover (*Trifolium repens*), which becomes deep carmine-red; but it is interesting to remember that there is a rose-purple variety of the plant in the Isles of Scilly. The intensifying of colour that follows transplantation to alpine heights has been proved in many cases. Plants growing at high altitudes sometimes show, when compared with others of the same kind growing at lower levels, an increase in the size of the flowers and in their fragrance.

One of the obvious features of the mountains is the low temperature, especially at night and in the winter. In relation to this we can understand the handicapping of growth, which warmth up to a certain limit always promotes. Plants constitutionally dwarfish will get on best, and likewise those which are rather thick-skinned. Perhaps a woolly covering may also have some protective value, but are we not a little too apt to think of plants in terms of our own constitutions and clothing?

A very important feature of the mountain climate is its tendency to dry things up—by the wind, by the thin air, by the sun. Therefore mountain plants show many adaptations towards preventing a dangerous degree of transpiration of water. The leaves are often leathery, especially in woody plants; others are hairy, which lessens the loss of water-vapour; others are varnished with wax; a few are succulent, with stores of water for periods of drought. Some alpine plants meet the difficulty in another way, by having a richly developed root system, going very deep, or spreading far, or having many branches in the soil. It must be remembered that the difficulty is twofold: there is the drying-up tendency, and there is the low temperature of the soil which lessens the capacity that the roots have for absorbing water.

Expressed technically, the difficulty that plants living at high altitudes have to face is "*physiological drought*." There may be plenty of water, but it is not readily available when the temperature of the ground is very low. The plant's problem is to do with little water, and it is interesting to notice, as we have done, some of the many solutions. The leaf-surface may be reduced to a minimum; the leaf-surface may be leathery, waxy, woolly; the leaf may be succulent but with a thick or varnished skin. And if it be asked why water is so essential, the answer is that water is needed as part of the raw material of the sugar and other carbon compounds, which the green leaf builds up in the sunlight, and that living matter cannot live without water. All the processes of life take place in a liquid medium; living matter itself is fluid.

Before we leave the heights we must at least state a question which inevitably rises in the mind, Where have our British animals, such as Red Deer and Mountain Hare, come from? But this is a very difficult question, which cannot be answered with anything like certainty. In Dr. R. F. Scharff's "History of the European Fauna" the view is upheld that our fauna mainly consists of three contingents or divisions—a northern, a southern, and an eastern, and that these correspond to migrations which can be proved to have arrived in this country at different periods in past times.

Dr. Scharff outlines the possibilities: "In early Tertiary times, when the climate all over Western Europe was moist and semi-tropical, a migration proceeded northward from the south-western corner of Europe. This was strengthened by Oriental migrants which had moved westward along the Mediterranean basin. Owing to geographical changes supervening, the alpine fauna was then enabled to colonise the

British Islands, and subsequently another migration had begun to come in from the south-east. The climate had meanwhile gradually become more temperate and drier. About the same time, or even earlier, an Arctic migration commenced to pass southward, and finally the Siberian animals poured into our continent."

The northern contingent may be illustrated by the Mountain Hare, the Stoat, the Ptarmigan, the Red Grouse, the Stickleback and the Miller's Thumb. A Siberian migration probably brought us animals like the Polecat and the Harvest Mouse, the Common Shrew and the now exterminated Beaver. To an Oriental migration, closely related to the Siberian, may be credited such animals as Red Deer and Rats, Water-Ouzels and Bullfinches. From South-western Europe may have come the Rabbit and the Pied Wagtail and the Irish Spotted Slug. To the Alps we may owe a few contributions, such as the Dormouse. We cannot, however, do more than raise the difficult question of the origin of our fauna and flora, and mention Dr. Scharff's book as the most convenient to start with in finding out answers.

CHAPTER IV

MOUNTAIN MAMMALS

The Stoat, or Ermine—The Mountain Hare—The Red Deer and other Deer—The Chamois—The Snow Mouse.

PROFESSOR HENRY DRUMMOND used to tell his students when they were dull the story of the adaptations of a mammal of the Andes which was marvellously suited for browsing on the sides of the steep mountains, having, for instance, the legs of one side longer than those on the other, so that it moved comfortably along a slope. It had, of course, to go round and round the mountain. This was a jest, obviously, intended to teach the students to be cautious in accepting everything they were told; but the general idea of the story was sound enough, that animals are often very well adapted to cope with the difficulties of particular habitats. Already we have seen that every animal is a bundle of adaptations or particular fitnesses: our question now is, How are mountain mammals suited to the conditions of their life?

One Christmas holiday we made an excursion over a shoulder of the Cairngorm Mountains, and we had the good fortune to see in one half-hour two kinds of white mammals. The one was the Ermine and the other the Mountain Hare—two creatures very different from one another, but alike in the peculiarity of being able to put on a white dress in the winter. The Ermine, or Stoat (*Mustela erminea*), is an agile carnivore, first cousin of the Weasel (*Mustela vulgaris*), keen of sense, determined in the chase, courageous in attack. It feeds on Rats and Voles, young Rabbits and Hares, and various birds, such as Grouse and Ptarmigan. In the Highlands of Scotland the reddish-brown Stoat always turns white in winter, becoming an Ermine; and, as the change of colour does not occur in Ireland and is rare in the South of England, it seems safe to say that the cold is the external cause that pulls the trigger. On the summit of Ben Nevis white Stoats may be seen all the year round. There is a twofold advantage in the blanching: it gives the Ermine a garment of invisibility that enables it to creep all unseen upon its victims, and it supplies the Ermine with the kind of dress that loses least heat in very cold surroundings. When the outside temperature is much lower than that of the body, there is less animal heat lost from a white dress than from a similar dress of any other colour, and the difficulty that rises in the mind when we think of the white dresses that we put on in the summer disappears when we notice that white absorbs less of the external heat than any other colour, and that it is not white *fur* that summer dresses are made of. But how is the change of colour brought about? The true answer seems to be that given by Professor MacGillivray, that when the winter comes on the red hairs of the summer dress are gradually replaced by new white hairs. Specimens in process of change are often seen, partly white and partly brownish-red, and the new white hairs are seen to be short and young.

In spring there is an opposite change, the white hairs moulting off and new red ones taking their place. While this is the true explanation, it does not exclude the possibility that some individual hairs may turn rapidly from brown to white. Indeed, Professor MacGillivray thought that "sometimes the brown hairs themselves, on the application of intense cold, become whitened." We know that a man's hair may turn white in a short time under great nervous strain, and that this is due to a rapid change in the colouring-matter in the hairs. The whiteness is due negatively to a removal of or a change in the brown or otherwise coloured pigment; it is due positively to the formation of numerous microscopic bubbles of gas. For the whiteness of white hair or of white feathers is the same as the whiteness of foam! When the blanching of hair is gradual there is, as the great Russian naturalist Metchnikoff showed, an interesting activity on the part of the phagocytes, or wandering amœboid cells, of the body. They behave like sappers and miners, entering the hair and creeping out again with a microscopic burden of colouring-matter. This is what goes on when particular hairs turn white slowly, but in most cases what happens in man is that the fresh growth of hair that is always going on is unaccompanied by the formation of pigment and is accompanied by the formation of gas vacuoles.

The Mountain Hare (*Lepus variabilis*), called by many other names—Alpine, Blue, Irish, and Variable—is first cousin of the Common Hare (*Lepus europæus*), and is a distinctively northern mammal. Its range extends from Ireland to Japan, but it does not now occur in England. When glacial conditions prevailed over Central Europe the Mountain Hare was doubtless common in southern countries; when the climate became milder it disappeared except from mountain ranges, such as the Pyrenees. Its bones have been found in England, but the country evidently became too mild for this strenuous creature. It does not differ greatly from the Common Hare, but it has many small peculiarities, such as whiter flesh. It has no particular resting-place or "form," but shifts from one hiding-place to another among the rocks and heather. It is often reduced in the winter to very short commons, and has been seen nibbling the lichens off the rocks. When the mountains are covered deeply with snow it comes down to the valleys. It shows the same kind of colour change as the Ermine, and its garment of invisibility, as we have called it, will help it on a background of snow to escape the keen eyes of Eagles and Hawks, Ermines and Foxes. An interesting little detail is that the Mountain Hare changes to white all but the tips of its ears, which are black all the year round, while the Stoat changes to white all but the black tip of its tail. The change from the yellowish-grey of summer to the white of winter is partly due to the growth of new white hairs, but it has also been proved that brown hairs may be changed into white ones. In the American Hare it seems that the process of putting on the white dress is always twofold—a growth of fresh hairs without pigment and with gas vacuoles, and a slow blanching of previously pigmented hairs. Thinking of the origin of this power of whitening that the Ermine and the Mountain Hare show, we must remember that colour is often a very variable character, that white animals very often turn up among coloured races, and that seasonal shedding of the hair is very common. Given these facts, we have no great difficulty in understanding in a general way how success and survival would reward those Stoats and Mountain Hares which possessed a constitutional tendency to grow white fur in very cold surroundings. It is not any longer a plasticity of *individuals:* it has become a *race* character, but it seems to require a trigger-pulling influence from without — namely, severe cold. When that is absent, as in Ireland, the Mountain Hare does not change its colour in winter.

The Common Hare is often seen on the shoulders of the hills, and the same may be said of the Fox and the Polecat. The roving Otter sometimes rests among the stones of a cairn on its journey from one river valley to another. But instead of dwelling on these we would pass to the Red Deer, which are at certain seasons very characteristic of the mountains.

The Red Deer (*Cervus elaphus*) is at home in Britain, in the Scottish Highlands, on Exmoor, and in the county of Kerry; it occurs in various parts of Europe, Western Asia, and North Africa. It is a magnificent animal, the male standing four feet high at the withers, the female about six inches less. The general colour is dark brown, with a yellowish patch on the rump, more marked in summer than in winter. As in all ordinary cud-chewing animals (cattle, sheep, and deer), there are no upper teeth in front of the mouth, the lower front teeth cutting the grass against a horny pad above; but the Red Deer can bite severely enough. There is a curious face-gland below the eye and another below the ankle surrounded by a tuft of hair. It is possible that the secretion of these glands helps mutual recognition.

The antlers are outgrowths of the forehead or frontal bone, and are confined to the stags—a general law to which an exception is found in the Reindeer, where they are usually present in the females as well as in the males. In the first year of his life the young Red Deer has no antlers; in the second year they are simple, unbranched prongs, six to twelve inches long; in the third year the branches begin, and every year their number is added to till the stag is about fourteen years old. When there are twelve "points" the antler is called "royal." But the antler growth starts at the beginning again each year, the previous year's growth being cast off at the end of each winter. If we look at a stag's head carefully we see that the antler springs from a thick bony stalk an inch or two inches high, which probably corresponds to the bony core inside the horns of cattle or sheep. At the top of the short stalk there is a rough folding of bone called the coronet, and it is here that the extraordinary process occurs by which the antler is shed each year. The new growth of antlers occurs from April till July, and during that time the antler is covered with a thin, hot, hairy skin, called the "velvet." It is rich in bloodvessels, and the nourishment these bring enables the bone to grow. In August the "velvet" begins to die away, and ragged shreds of it hang on the antlers till the end of August or the beginning of September. When the antlers are clear the fighting begins.

The stags fight fiercely with one another, stabbing at heart or belly with the lowest branch or "brow-tine," which points forwards and upwards, or pushing with the antler as a whole. In the combats a good deal of use is made of the hoofs, especially those of the forefeet. It is hardly necessary to say that the Red Deer may be very dangerous to man at the breeding season (September and October). The stags are greatly excited and roar loudly. Their voice is said to carry about two miles, and it excites both the hinds and rival stags. What each stag is after is to attach to himself as many wives as possible and to keep intruders from interfering with his herd and trying to lead some of them away.

The fawn, usually only one, is born in May or June, after the mother has carried it for about eight months, and, as is the case with many Deer, it is spotted. Sir Harry Johnston, in his "British Mammals," tells us that: "The mother attends and defends her fawn with the greatest care and bravery. She teaches it to conceal itself instantly on the approach of danger, the signal being generally a tap with the forefoot." In the summer time the hinds and fawns usually live apart from the stags, as we noticed in our first study, and they are often to be found at much lower levels.

But how is the Red Deer adapted to the mountains and moorland? They are fond of the grass that grows in damp places among the heather; they can also eat the shoots of the heather and some other heath plants; they keep a lookout for mushrooms and other edible Fungi. But we suspect that the true answer is that Red Deer are rather forest mammals than mountain mammals, and that they have often a very hard time of it, especially in winter. At that time they often wander restlessly seeking food both night and day, and we have known starving Deer come down begging to the houses of the village; we have known them swallow small Rabbits! In the summer, when pasture is abundant, they have a comfortable life, and they rest in hiding during the heat of the day. We do not mean, of course, that they are lacking in adaptations, such as a thick, close-set coat, extraordinarily keen senses of smell, sight, and hearing, and great swiftness of foot. They are also strong swimmers, easily able to cross broad rivers and lakes. But the clearing of the forests has made life difficult for the Red Deer. There is convincing evidence that the size of the antlers is less than it used to be in olden times.

Some of their peculiarities are interesting. We have known them travel a long distance to get an early morning lick at the rocks on the seashore, for they are very fond of salt. There is no doubt that they gnaw at their cast-off antlers.

The Fallow Deer (*Cervus dama*) is mostly a park animal nowadays, though there are some nearly wild herds here and there. It is smaller than the Red Deer, the full-grown buck standing about a yard high at the withers; the antlers are quite different, being flattened or palmated towards the top; there are usually, though not always, rows of white spots on the yellowish-brown hide; the tail is about six inches long, that of the Red Deer being much shorter. Fallow Deer are gregarious all the year, but the bucks and does are usually in separate bands. There is a combination at the beginning of winter, which may be a reminiscence of days when they had to unite their forces against wolves. The Romans often get the credit of introducing the Fallow Deer, but *at the most* it could only be reintroduction, for the remains of deer very like our Fallow Deer have been found in deposits much older than the Roman Invasion.

The shell-marl below the peat in Ireland, and various cave-deposits and river-gravels in England have yielded remains of the splendid Irish Deer (*Cervus giganteus*), often badly called the Irish Elk. This extinct species had the largest and most massive antlers in the whole Deer family, for the span was sometimes eleven feet. The animal stood about six feet high at the withers, and was widely distributed throughout Europe. It seems to have lasted in Ireland until comparatively recent prehistoric times. Its extinction was probably due in the main to a commonplace cause—man's persecution; but we cannot but suspect that the momentum of evolution had carried the growth of the antlers beyond the bounds of safety. It is desirable to drop the name Irish Elk, for the creature was not an Elk. Moreover, the true Elk (*Alces machlis*), still surviving in North Europe, was a contemporary of the Giant Deer in Ireland. So also was the Reindeer (*Rangifer tarandus*), which used to occur throughout Great Britain and Ireland. There are records, indeed, we believe, which indicate that some specimens lingered in the North of Scotland till about the twelfth century. It will be understood, however, that Red Deer, Fallow Deer, and Irish Deer may all be included as first cousins in the genus *Cervus*, whereas Elk and Reindeer are not related to them nor to one another.

Very different from any of the forms we have mentioned is the little Roe Deer (*Capreolus caprea*), which is widely distributed in Europe and Western Asia. It is still common in Scotland and occurs in a few parts of England—a forest-loving deer. The full-grown buck measures only about two feet high at the withers; the doe is still smaller. The general colour is reddish-brown in summer and yellowish-grey in winter, the doe lighter than the buck. There is a large white patch on the rump, which may help the fawns to follow their mother. The antlers are small, rugged, and comparatively simple, having in most cases only three tines.

The Roe Deer is fond of Conifer plantations and of glens with copses of birch and hazel. It is not gregarious, but goes in pairs or in small parties. The males and females remain together throughout the year. Two fawns are usually born at a time, in May or June, and they show, like many young Deer, several longitudinal rows of spots. They remain with their parents till winter comes, and are very carefully looked after. Roe Deer usually feed in the morning and evening, and lie hidden among heather and bracken throughout the day, chewing the cud.

The cud-chewing of Ruminants—*e.g.*, cattle, sheep, and deer—is a habit as remarkable as it is familiar. (1) The grass and herbage is hastily swallowed, perhaps because of the ancient necessity for restricting exposure to the attacks of Carnivores. (2) It passes down the gullet into the first chamber of the stomach, the large paunch, the internal surface of which is like velvet pile. (3) An overflow of the more fluid material may pass into the second chamber, the honeycomb bag which has a curious hexagonal pattern on its walls. (4) Having filled its paunch and perhaps some of its honeycomb bag, the Deer, or whatever Ruminant it is, seeks a place of safety where it may chew the cud without risk of molestation. By reversing the swallowing movements it forces the grass in lumps, or "boluses," up its gullet into the mouth. This is a little as if vomiting had become a habit. (5) In the mouth the food is thoroughly chewed and mixed with saliva. (6) It then passes down the gullet for the second time, skips the paunch and the honeycomb bag, and travels along a muscular groove, anterior to the latter, into the third chamber—the manyplies. In this it passes between a number of partitions which serve as a sort of strainer. (7) Finally, the food reaches the fourth chamber—the reed, or true stomach. For the first three chambers really belong to the lower end of the gullet, and no digestion takes place in them except in so far as the salivary juice from the mouth may operate. But all this is a digression started by the Deer lying among the bracken.

The Red Deer on the hills take our thoughts to allied mountain mammals. Very characteristic of the high mountains of the Continent of Europe, from the Pyrenees to the Caucasus, is the Chamois (*Rupicapra tragus*), which is really a goat-like Antelope. It stands about two feet high at the withers, about the same as our Roe Deer. Chamois go about in flocks of a dozen or so; the full-grown males keep by themselves except at the pairing season in October, when rivals fight fiercely and often fatally. Two particular fitnesses may be noted: (1) There is shaggy hair, chestnut-brown in winter, greyish in spring, and underneath this an under coat of grey wool, a valuable protection against the cold; (2) the hoofs have their outer edges higher than the soles, and this gives the feet a great grip of the rocks—a grip that helps us to understand how the Chamois pull themselves up after a big leap and how they find a foothold on what seem to be inaccessible crags. In summer the Chamois go far up the Alps to near the line of perpetual snow, and they frequent tracts of mountain with a northern exposure, partly to avoid the glare of the sun and partly to escape the battery of falling stones which the summer sun often sets loose. In winter they keep to lesser heights. As to the Alpine Ibex (*Capra ibex*), a wild goat that ascends to heights even higher than those which the Chamois frequents, a wary, gregarious creature with splendid horns about two feet long, one regrets to learn that it has been hunted almost to the limit of extermination.

Of great interest among Mountain Mammals is the Snow Mouse, or, accurately, Snow Vole (*Microtus nivalis*), of the high Alps. It is a little creature, about five inches long in body and two in tail, somewhat variable in colouring but usually rusty-grey or whitish-grey, and with the tail sometimes white. Perhaps there is no other mammal that lives so hard a life, for it is rare below 4,000 feet unless there is a climber's or goatherd's hut to pillage, and it ascends from the snow-line, where it is most abundant, to the summit of the mountains. Unlike many of its kindred, it does not migrate in hard times, but keeps doggedly to its lofty retreats, and even in midwinter it may be seen scampering over the snow. Unlike the Marmot, another Rodent of the mountains, it does not fall into a winter sleep, but continues making tortuous burrows beneath the snow, mining its way from root to root. The only special adaptation is a storing habit, for in summer days it accumulates provender in its nest, which is often found among the loose débris of rocks. The store consists of chopped grass, gentian roots, and similar hard fare, the Snow Mouse being consistently vegetarian. There are no other mammals at such altitudes, and birds-of-prey are few, so that we may say that the Snow Mice have found an asylum on the high Alps. But the life is so penurious and exacting that we naturally look for some explanation, and that is not in general terms very difficult. Dr. Baumann points out that the Snow Mouse was long ago one of the "tundra" animals that flourished over a considerable part of Central Europe during glacial and inter-glacial periods when the uplands were covered by a great ice-sheet, now encroaching and again receding. The bones of the Snow Mouse are found in deposits belonging to that "tundra" time along with those of Reindeer, Arctic Fox, Mountain Hare, and Collared Lemming (*Cuniculus torquatus*). As the climate became milder and the ice-sheet melted, the tundra-life became impossible. Some of the tundra animals, like the Reindeer and Arctic Fox, may have migrated northwards; the Snow Mouse went up the mountains, higher and higher. This fits in well with the fact that the Snow Mice occur to-day in scattered communities, separated by large mountainous tracts where there are none of them. These scattered communities represent to some extent separate migrations from the low grounds. Thus we see that the Snow Mouse is a very interesting historical relic of the Ice Ages, surviving at great heights in virtue of a constitution that "likes cold" and in virtue of no inconsiderable power of enduring hardness.

CHAPTER V

SOME BIRDS OF THE HEIGHTS

The Golden Eagle—The Blackcock—The Raven—The Snow Bunting—The Mountain Linnet—The Ring Ouzel.

EVERYONE will agree that Storm Petrels are birds of the open sea, that Water Ouzels are birds of the streams, that Curlews are birds of the moorland and seashore, that Waterhens are birds of the ponds, that Woodpeckers are birds of the forests, and so on. The question is, whether there are birds distinctive of the heights. We think that the question, if not pressed too closely—for birds are extraordinarily plastic, this being their privilege of brains—should be answered in the affirmative; and we have taken six examples—the Golden Eagle, the Blackcock, the Raven, the Snow Bunting, the Mountain Linnet, and the Ring Ouzel.

The first place must be given to a magnificent bird, the Golden Eagle (*Aquila chrysaëtus*), which holds its own in the Scottish Highlands, and has a wide range in many mountainous regions of the Northern Hemisphere. It has suffered from its size (the female bird is within an inch of being a yard long, and the male within four inches), which makes it a good target for ignorant and ruthless "shots," and also from absurd stories that have been circulated about its ability to carry off children and its habit of killing sheep. But it has also suffered from the gradual spread of agriculture, which has meant a reduction or restriction of part of the Golden Eagle's food-supply, such as Hares and other small mammals, Grouse and other birds. Collectors are also to blame, especially "professionals." Moreover, it is a slowly multiplying creature, usually having only two offspring in the year. It is welcome news that the Golden Eagle is on the increase in the Highlands of Scotland, for it is a noble bird—a national asset of high value—and if it occasionally gives a *coup de grâce* to a sickly lamb or a disabled fawn, there is no harm in that. Even in the interests of grouse-shooting it is worth preserving, for it tends to winnow out the weaker birds.

The nest is sometimes built on the side of a cliff and sometimes on a tree; it is a bulky structure, and is used many times over. The framework consists of branches and twigs; the interior is made comfortable with Grasses, Woodrush, and Moss. All the brooding is done by the female, but the male bird may bring some of the food which she gives to the young ones, notably livers of Hare and Rabbit and titbits of birds.

Thanks to Mr. H. B. Macpherson's careful study of a Golden Eagle's eyrie in the Grampians (see "Home Life of a Golden Eagle"), we have accurate pictures of what goes on during the brooding time. A few outstanding facts may be selected. After the eaglets are hatched the mother hunts for them, feeding them at first twice a day—at dawn and at dusk. The Grouse that are brought to the eyrie are plucked and headless; the Hares and Rabbits are skinned and made ready in a larder distant from the nest; the youngsters get only digestible food, being unable for some weeks to

THE GOLDEN EAGLE AT HOME

FROM "THE HOME-LIFE OF THE GOLDEN EAGLE" BY H. B. MACPHERSON

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form pellets; the mother feeds herself at the same time; for the first two months the nest is kept scrupulously clean. Gradually there begins a deliberate education of the eaglets in the art of treating the food that is brought to them, and they learn to swallow fur and bones. They begin to play a little, to make short excursions from the nest on to the shelf of rock, to flap their wings. They eat prodigiously, and when they are about eleven weeks old they are ready for their first flight. The nest has been allowed of late to become very dirty, and it is time for a change. But even after flight has been learned the education of the eaglets continues; they have to be taught how to hunt and how to kill, how to carry and how to skin, and all the alphabet of danger sounds and sights. The nurture and schooling last for five months, and then the youngsters are driven from their home with a firmness that is as kind as it seems to be cruel. In the Highlands the eaglets have to be shielded from rain and snow; in some parts of North America they have to be sheltered from the heat of the sun. It is very interesting to know that each parent bird, itself feverish, will try to make a sunshade of its body, to save the panting prostrate young. Even among eagles we see that the reward of survival comes not only to sharp beak and talons, but to self-sacrificing parental care.

The Golden Eagle seizes the crouching Grouse by the head and the Hare by the head and haunches; and the death it brings must be almost instantaneous. We once timed one catching and killing a Thrush; it was all over in less than half a minute. So we cannot say much about the bird's cruelty.

Along with the Golden Eagle we may mention a few other birds of prey to be seen on our mountains: the Peregrine Falcon, the Sparrow Hawk, the Kestrel, the Buzzard, and the little Merlin. For other countries we must add many more, such as some of the Vultures, which reach a climax of voracity in the Condor of the Andes.

In our third study, in connection with special fitness for the mountains, we discussed the Ptarmigan. Now we must say a little about the Black Grouse (*Tetrao tetrix*), which is the Ptarmigan's cousin. The male, called the Blackcock, is distinguished by his metallic black colour, with a bar of white on the wing and white below the tail, from his mate, the Greyhen, who has a ruddy-buff plumage, barred and freckled with black. From July to September, however, the Blackcock has what is called an "eclipse" dress, which means that his splendour is somewhat dimmed, as the sun's by the moon's shadow. He moults the fine black feathers of his head and neck and tail, and he is for a time not very unlike his mate. It almost seems, as a great naturalist puts it, as if the cloak of his brooding mate is dropped over him for a while. The tail of the cock is beautifully lyre-shaped, while that of the hen is deeply forked.

Perhaps Black Grouse are more characteristic of moorland than of mountains, but they are often seen at considerable heights. They also frequent forests of birch and pine. The adults feed on young heather points, blaeberry shoots, berries, and seeds; the young require insect food, such as the young stages of Ants, which their mothers help them to find. The nest is a scraping in the ground with a scanty lining; the six to ten eggs are yellowish-white, with orange-brown spots. Unlike the Red Grouse and Ptarmigan, the Blackcock is polygamous, and in late summer one sometimes sees him of an evening resting on a Birch-tree with his four or five wives round about him—quite an Oriental picture! In early spring there is a remarkable tournament, or "lek," in which the cocks first fight resolutely with one another and afterwards display themselves before the Greyhens.

It was in Glen Brora, in Sutherlandshire, that we once saw this tournament and display—an unforgettable spectacle. On one of the shoulders of the hills there was a walled-in sheepfold and beside it an almost level sward with small Birch-trees and Alder-trees round about. We had started in the very early morning and hidden ourselves in the sheepfold. When the sun began to show itself at dawn we had the good fortune to watch the Blackcocks strutting and dancing on the jousting-ground. The red wattles above the eye were extraordinarily vivid, and the sheen on their feathers was so brilliant that we could hardly believe that they were the birds we knew well in everyday life. As they assembled they kept on calling—we suppose for the Greyhens to come to witness their jousting. We saw two rivals enter the lists with lowered head and wings and arched tail. They struck at one another with beak and wings, and the victor crowed. By and by the Greyhens appeared quietly on the scene and sat down on the branches of small Alder-trees. This seemed to strike a new note, for the rivals began to jump and dance, uttering hoarse cries. The Greyhens did not seem to us to be much excited or even much interested, but there was no mistaking the passion of the lusty Blackcocks. We were rather excited ourselves, for it was a wonderful spectacle—the sunrise, the growing light on the hills, the green sward, the transfiguration of the male birds, the fighting and the bluffing, the display and the dancing; but all of a sudden the curtain fell. In our preoccupation, anxious to see a little more clearly into the mysteries, we raised our heads a little above the level of the wall of the sheepfold. There was a clapping of wings and a gust in the Alder-trees, and all was over. The stage was there, but the actors were gone.

Once common in Britain, the Raven (*Corvus corax*) is now very rare. But there are still some secluded cliffs, especially near the coast, where it survives persecution. It can be known at once from the Rook or the Carrion Crow by its large size, the male being an inch over two feet long. In some parts of the Northern Hemisphere Ravens make their nests together and unite in flocks when there is some unusual abundance of animal food, and there are a few communal roosting-places in this country. On the whole, however, one is very lucky to see a pair!

We know one sombre Highland glen where the mountains come down to the sea, and on a precipice half-way up the heights on one side there is a roosting-place where a number of Ravens spend the night. We have tried to get near it, but the ascent proved beyond our powers. We wished to see one of the shelves which are said to be littered with interesting castings of undigested food—bones, hair, feathers, shells, and what not—and we wished some night to hear in the silence of the hills how the ravens croon themselves to sleep, uttering reminiscences of the sounds they have been listening to throughout the day. Mr. F. B. Kirkman writes in "The British Bird Book": "From the growing congregation on the ridge there descended through the thickening dusk the strangest of evensongs—a weird, wild medley of many sounds: the barking of dogs, the bleating of goats, the lowing of cows, the becking of grouse calling across the moorland, and now and then the deep belling challenge of the stag." Ravens are fond of mimicry.

All that we heard, however, was the deep and harsh "whow, whow," uttered defiantly as birds came and went, and it seemed harmonious with the sombre scene. Apart from mimicking, the Raven, being a big-brained bird, has a good deal to say, and in some countries where it is less continually on the defensive its varied notes rise at the mating season into "song." An affectionate courtship has been described, with beak kisses and plumage display, with jumping from the ground, gambolling on the wing, and strange sideslips through the air. The big nest of sticks and twigs, lined with fur and wool, is built in February or March on a crag; there are from three to five bluish-green eggs flecked with olive-brown; both parents brood; the young are fed on all sorts of animal food suitably minced down. The Raven is a voracious bird of prey, devouring sickly lambs and carrion, young Hares and Rabbits, birds and eggs, and so on down to Frogs and fishes, Crabs and insects, and even Worms. It destroys large numbers of Rats, and it is one of those birds that keep the balance of nature steady and that sift out weakly and dying creatures.

Apart from man it has few enemies, for it will face up to Eagle and Hawk. In some cases the phrase "facing up" is anything but appropriate, for the Raven, challenged in flight, will allow itself to be almost pounced upon, and will then suddenly turn upside down in the air, showing a disconcerting readiness of claws and beak. This is the Raven's way, for all who have been able to make its close acquaintance are agreed in admiring its shrewdness, resourcefulness, and cunning.

Very characteristic of some European mountains, such as the Alps and Pyrenees, but now rare in Britain and almost confined to cliffs near the coast, is the very attractive Chough (*Pyrrhocorax pyrrhocorax*), easily known by its relatively small size (sixteen inches long), its red legs, and its red curved bill. It usually lives in isolated pairs, unlike its first cousin the Alpine Chough (*Pyrrhocorax graculus*), which is gregarious. It is a vivacious, clever, affectionate bird; and one of its interesting features is that it pairs for life. The male brings palatable gifts to his mate, and he has been seen "to manifest his affection by softly rubbing the back of her head with the underside of his coral beak."

Among stones on the Cairngorms and some other Highland mountains the Snow Bunting (*Plectrophenax nivalis*) sometimes makes its grassy nest, lined inside with hair and feathers, and successfully brings up its young. This is interesting, because the bird is really at home in the Far North, and is for the most part a winter visitor to our islands. We welcome them in the north of Scotland at the beginning of each winter as they come in little bands seeking ground less hopelessly covered with snow. The white feathers in the long wings catch the eye, and the flight often looks like a series of bounds through the air. They change their direction often, as if they were seeking something, which is no doubt the case. For when they reach a bare stubble field they sink to the ground and begin eagerly to eat little seeds and perhaps an occasional small insect. In summer they live on the mosquitoes and midges so common in North Scandinavia and similar countries. There is something very attractive in these winter visitors, in their suggestion of snowflakes in the air and in their soft notes as they fly. Some naturalists have compared their flight, when they are not "rushing," to that of butterflies, and it is quite possible that the resemblance is of protective value. More plausible, however, is the suggestion that the white patches of the plumage, especially in winter, make the flying bird a difficult target for the Hawk. The common name "Snowflake" suggests the resemblance of the flying bird to a feathery flake driven by the wind, and we have often seen the visitors appear suddenly above our heads flying southwards in front of an approaching snow-blizzard. We must not say more, but those who climb on the northern Scottish "Bens" should look out in the summer for the Snow Buntings—still comparatively few and far between—who have chosen to spend the whole year in our country.

A common but shy little bird of the heather-covered moors and mountains is the Twite (*Linota flavirostris*, which translated into Scots is "Yellowneb Lintie"). It gets many names indeed—Mountain Linnet, Heather Lintie, and Twite, the last referring to the single syllable it so often utters. It is a first cousin of the Linnet and the Redpolls. Among the heather it seeks for seeds all the year round, but it comes lower down when winter sets in. The nest, made of root-fibres and grass to the outside, hair and feathers to the inside, is built in all sorts of sheltered corners; the three or four eggs are pale greenish-blue blotched with reddish-brown; the young are fed on seeds from the parent's crop. There is not much that is striking about this little brownish bird (the male has a rose-red rump), but we often raise it from among the heather and see it flit on ahead and settle down on a grey boulder. It has not much to say, but we are always glad to hear it.

The Ring Ouzel or Mountain Blackbird (*Turdus torquatus*) is readily known by the crescent of white on the throat—broad and brilliant in the full-grown male, narrower and duller in the female. It gets many other names, such as Moor Blackbird and Crag Ouzel, both of which suggest its fondness for the heights. It is about the same size as a Blackbird. It is very characteristic of our mountains and moors, making its nest among the heather, in broken banks, and by the sides of streams. In its nest and its eggs, very like the Blackbird's, it reveals its relationship, for it is just a Mountain Blackbird. In his indispensable "Manual of British Birds" Mr. Howard Saunders writes: "Few birds are bolder when their young are approached, the parents flying round the intruder, uttering their sharp alarm note of 'tac-tac-tac,' 'tac-tac-tac'; but the song is somewhat monotonous, and derives its chief charm from the scenery in which it is heard." For the Ring Ouzel is a bird of the hills and glens. It feeds on earthworms, slugs, grubs, and berries. In England its chief haunts are the spurs of the Cumbrian and Pennine ranges, the Welsh mountains, and the Devonian hills; in Scotland it is not uncommon on the upland moors; in Ireland it frequents the mountainous districts of all the four provinces. For the whole of the British area and for the mountainous parts of Central Europe it is a summer visitor.

When the flocks of Ring Ouzels that arrive on our shores in spring reach the high grounds, they break up into pairs, and these, as in many other cases, take possession of particular "territories," each with a big boulder or the like as centre. Then follows an interesting courtship—strutting, parading, leaping into the air, fluttering, and chasing, while all the time the cock-bird keeps up a twittering song, now subdued and again excited. After the nesting and brooding and nurture are over, the Ring Ouzels descend from the high grounds at the end of summer and unite again into flocks. These congregate in the low grounds and leave our shores in the late autumn.

CHAPTER VI

PLANTS OF THE MOORLAND

Heath and moor—The secret of the Heather—Other heath plants—The problem of the high moor—Bog Moss—The making of peat—Butterwort and Sundew—Some other moor plants—Fly Toadstools—Fairy rings—"All things flow."

We mean by moorland a wide expanse, more or less level or undulating, open to the wind and the sun, covered with short vegetation and with very few trees. The word suggests spaciousness, solitude, lack of shelter, and rather unfriendly soil. We wish to use the word in a rather wide way.

The term "heath" is strictly applied to a tract of poor sandy soil with little lime in it, where the Common Heather or Ling and related Heathers form the prevailing vegetation. A heath may be on low ground near the shore or it may be on the uplands. A heath vegetation covers the sides of many mountains, but we are not including steep slopes in our picture of moorland. As time goes on the surface of the heath may accumulate a carpet of heather peat, and this brings a heath nearer a true moor.

For the term "moor" is best applied to more or less level or gently undulating tracts where abundant peat has accumulated or is accumulating. When the soil is poor in lime and the standing water is coffee-coloured with organic matter in solution, the term "high moor" is often used—the characteristic feature being the hillocks of Bog Moss (*Sphagnum*). This true moor may be comparatively dry or it may be a peat bog. When the soil has plenty of lime in it and the vegetation is more varied than in a high moor, the term "meadow moor" is used, and as peat disappears this passes into a meadow.

The subject may be followed up in Schimper's "Plant Geography" (Oxford, 1903); but what we have said may perhaps suffice at present. Our general scheme is the following:

Heath vegetation on steep hillsides.

Heath vegetation in forests.

Heath vegetation on open, undulating expanses; with little peat	Moorland.
Heath vegetation on open, undulating expanses; with the beginning of peat	
Moor vegetation, where there is much peat, and little lime — the high moor, whether dry or boggy	
Moor vegetation, mixed with other types, where there is abundant peat and plenty of lime—the meadow moor	

Meadow vegetation, without peat.

In North Temperate regions there are enormous tracts of country which are covered with Heather and related plants, but show little else. One of these immense heaths stretches along the southern shores of the Baltic for hour after hour of railway journey, and there are many small counterparts of this in Britain. The dominant plant is the Common Ling, or Heather (*Calluna vulgaris*), and with this go the Heaths, or Bell Heathers (*Erica*), some short berry-bearing plants, and some small shrubs like Furze, Broom, and Juniper.

The Common Ling, or True Heather, may be known at once from the Heaths, or Bell Heathers, by having much smaller and more numerous flowers, in which the calyx is longer than the corolla and both are coloured rosy-purple, sometimes varying to white. The leaves are *very* minute. The Heath, or Bell Heather, has fewer but finer and larger bell-shaped flowers, with the calyx not coloured. Its leaves, though small, are larger than in the Ling. The Fine-leaved Heath (*Erica cinerea*) has its crimson-purple flowers in whorls at different levels up the stem; it is smooth and dark green. The Cross-leaved Heath (*Erica tetralix*) has all its rose-red flowers in a drooping bunch at the top of the stem, and is typically downy and grey. In Heather as well as in Heath the calyx and corolla dry without crumpling up, and keep their shape, as everyone knows, through the winter. We have not in these studies troubled with distinctions between kinds, and in a sense it matters little whether one calls a plant Heather or Heath, Ling or Bell Heather, Calluna or Erica. What does matter is that we see the differences between two very common and very characteristic plants. Just as there are two great kinds of mountains, so there are two kinds of heather plants on these mountains, and unless we are to be content with the blurred vision which seems to be all that moles can have, we should make up our minds to know the one kind from the other. It is easier for the Heathers than for the mountains. This sort of question may be profitably followed up in a book like Step's "Wild Flowers Month by Month" (2 vols., 1906) and in Hooker's "Students' Flora."

But the important question is, why Heather should succeed well where most other plants fail. The first part of the answer is that heather plants are very resistant to exposure. Their stems are wiry and their leaf-surface is much reduced. In the Heather the leaves are only about a quarter of an inch long; they are closely packed in four rows. In the Heath the outer margins are turned back, and screen the lower surface, on which there are the little openings (or stomata) through which transpiration of water takes place. This is well adapted for life on exposed areas, scorched by the sun in summer and swept by the wind at every season, where there has to be economy with water. Even when there is a heavy rainfall and plenty of water on the heather-covered moorland, this is apt to be in an acid state which the roots cannot readily utilise.

The second part of the answer is rather unexpected; it concerns the roots. It is not merely that these are long and travel far, as you will see on trying to pull one up; it is that they have entered into partnership with a Fungus. The outer surface of the young root of the Common Heather bears no root hairs, but is covered with the transparent threads of a Fungus. These threads or hyphæ enter the root and coil in its cells; they grow into stem and leaves; they penetrate even into the ovary of the flower; they infect the envelopes of the seed. Perhaps the Fungus was a parasite to begin with, but it has become a partner. It probably enables the Heather to utilise the organic matter that there is in the soil when peat begins to form, and perhaps it enables the Heather to utilise the free nitrogen of the air, just as is done by the bacteria in the root tubercles of leguminous plants, such as Peas, Clovers, and Lupines. This, then, seems to be the secret of the Heather and of other plants in the same family (Ericaceæ), that they have entered into a partnership, or symbiosis, with a Fungus. As Dr. Rayner says: "They have solved the problem of growth on poor and unpromising soils, but have solved it at the price of their independence." The partnership is technically described as "mycorhizic," which means "fungus-rooted." The interesting subject may be followed up in Professor F. O. Bower's "Botany of the Living Plant" (1919), from which we take the following quotation. "The germ is free from the hyphæ in the seed, but infection takes place shortly after germination. Without the Fungus, as shown by pure sterile cultures, the seedlings do not develop roots, and though they remain alive for months their growth is stopped. On infection with the right fungus they develop normally. Thus the synthesis (or binding together) of fungus and plant has been experimentally accomplished. The conclusion is that *the Symbiosis is a necessary condition of normal life in the Common Heather*. Similar fungal infection of the seeds in the ovary is the rule in other Ericaceæ examined." This, then, is another illustration of the close interlinking of the lives of different creatures, to be put alongside of the Lichens which we studied on the top of the mountain.

Some other members of the heath vegetation deserve consideration. There is the trailing Crowberry (*Empetrum nigrum*), with wiry stem and crowded leaves and small black fruits which Grouse are fond of. The leaf has its margins so much bent back that they meet one another beneath, shutting in the under surface, which bears the transpiration pores or stomata. This, as we have seen, is characteristic of Heaths, and Professor Miall notes that a certain moorland grass (*Nardus stricta*), which grows in close tufts, has the same habit. "Its leaves look wiry or even bristle-like, because they are rolled into slender and rather stiff hollow cylinders." This sheltering of the transpiration surface by rolling round the margins will lessen the loss of water in summer drought; but Professor Miall points out in his delightful "Round the Year" (1896), a book that compels one to think, that the rolling round is seen in some plants which are little liable to drought. It may be a protection against wind, which forces loss of water from the leaves into the air, and yet reduces the temperature so that the absorption of water from the soil is difficult. "Drought and cold and wind all tend to parch the tissues or, at least, to cut off the supply of water taken in by the roots, and diminished transpiration is the remedy of nature for all three contingencies." One other idea must be noted, however, that sometimes when there is plenty of water in the soil, it is *chemically* of such a nature that its absorption is difficult. It is too full of organic salts. To sum up, the rolled-round leaves of the Crowberry, the Heath, and some other moorland plants are well suited for economising water, not only when it is scarce, not only when there is danger of losing too much, but also when it is abundant in the surrounding soil yet difficult to absorb.

Another heath plant is the Bearberry (*Arctostaphylos uva-ursi*), with trailing woody branches, bright pink, bell-shaped flowers, and small red "berries," really little drupes or stone-fruits. Its leaves are woolly on their stalk and margin, and this must lessen the risk of over-transpiration. They remain green through the winter. There is on Scottish mountains a rarer kind of Bearberry (*Arctostaphylos alpina*), which ascends to 2,700 feet; its flower is white and its fruit black. It might well be called a British alpine. Its leaves are unlike those of the other kind, in falling off when the winter sets in. Here it may be noticed that most of the heath plants are evergreens, in the sense that their leaves last in a green state through the winter and are replaced all at once in spring. This is different from the evergreen condition of the Holly and Ivy, for instance, where the leaves are changed as it were piecemeal, a few at a time.

The evergreen condition is probably the more primitive, the autumnal fall of the leaf being an adaptation to conditions where the contrast of summer and winter is very marked. In severe conditions it is advantageous that the leaves should fall, for it reduces the surface from which water may be lost, and it helps to bring the plant into a state of comparative inactivity which makes resistance to the winter easier. And if the old difficulty arises in the mind that there is plenty of moisture in winter, we have to recall the explanation that the soil is cold and that the absorption of water by the roots is difficult at low temperatures. There may be "physiological drought," as it is called, where there is no physical drought.

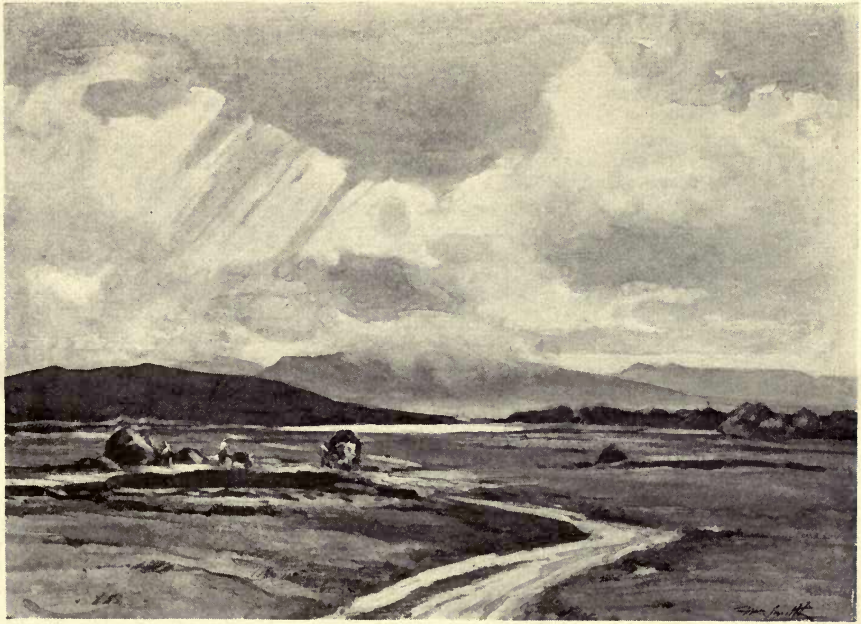
But it is difficult to give any reason why moorland plants should be evergreens. Would it not be better to reduce the loss of water to a minimum by shedding the leaves in autumn? The answer given by Professor Schimper in his "Plant Geography" (Oxford, 1903) is that the evergreen habit is *not* suited to heath or moorland conditions; it is a legacy dating from other and more hospitable surroundings. It is a hereditary characteristic of the Heath family (Ericaceæ), which is retained under the most diverse climatic conditions. We should also notice that the leaves of many evergreens are leathery, which also lessens the loss of water, and reduces the risk of being evergreens in conditions where this is not a profitable habit.

Also characteristic of heaths are three nearly related plants, different kinds or species of Vaccinium. The first is the Blaeberry, Billberry, or Whortleberry (*Vaccinium myrtillus*), with the young leaves a beautiful rose colour, hinting at the rosy-greenish flower. The leaves fall off when cold weather sets in, unless it be in very sheltered places; but the young shoots are green and probably do some leaf-work (photo-synthesis) in the winter sunshine. Everyone knows the delicious flavour of the dark blue fruit. The Blaeberry often forms a thick carpet in Pine forests, and this familiar fact may be taken as giving us a useful hint—that some of our heaths have grown up in place of forests that have been cleared away.

The second kind (*Vaccinium uliginosum*) has a pale pink flower and a berry smaller than that of the Blaeberry, but of the same colour. It ascends to 3,500 feet in the Scottish Highlands. The third kind is the Cowberry (*Vaccinium vitis-idæa*), with leaves like those of Box, crowded flowers, and an acid, red berry, half an inch in diameter. There is a fourth kind, the Cranberry (*Vaccinium oxycoccus*), but it belongs to the peat-bog vegetation. It has red flowers and dark red berries, about a quarter of an inch in diameter. There is some interest, we think, in noticing that the first two kinds of Vaccinium lose their leaves at the approach of winter, while the Cowberry and the Cranberry are evergreen. There is some value, we think, in mastering on a holiday, with the help of Hooker's "Students' Flora," or some similar book, the different berry plants of the heath. Even if we forget them before our next holiday comes, we have the satisfaction of having refused to be "mole-eyed."

Besides the heath plants which we have mentioned there are other tenants often present, which are not so characteristic—shrubs like Juniper, Broom, and Furze, small Willows (*Salix aurita* and *Salix repens*), and various Grasses like *Aira flexuosa* and the May-Weed Grass (*Nardus stricta*), which is too harsh for the Sheep to eat.

But we have said enough. What we wish is a general picture of the Heather and the Heaths, the Crowberry and the Blaeberry, which in virtue of certain fitnesses and habits, make the best of poor soil and exposed situations. A heath is typically treeless, but small Birches and Oaks are not uncommon, and an occasional Scotch Fir may stand as a relic of past times. For some heaths have taken the place of woodland that has degenerated. In regard to the Gorse, or Whin (*Ulex europæus*), and the Broom (*Cytisus scoparius*), which sometimes colonise heathland, it is interesting to recall Professor Weiss's observa-



A "HIGH MOOR" WITH PEAT-CUTTERS IN THE FOREGROUND AND A LOCH IN MIDDLE DISTANCE

RANGES OF HILLS IN THE BACKGROUND

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tions, which show that Ants distribute the seeds of these plants. They push them along the ground, biting at the orange-coloured "oil-body" as they go. As Ants often utilise human tracks as their roads, we can understand why the Gorse and Broom should often be found alongside paths on the heath.

"High moor" is a technical term for peat-covered stretches where there is very little lime. The water contains organic acids (humic) dissolved out from the peat, but it also contains abundant organic salts (humates) of similar origin; and these humates make life difficult for most plants. In the "low moor," which is rich in lime, the humates unite with the lime and cease to be soluble in the water. Thus the water is freed from them and a much more varied vegetation is possible in the low moor, or meadow moor. *The first difficulty to be faced in the high moor is the abundance of these organic salts in the coffee-brown water.* It is possible that the partner Fungi associated with Heather and Crowberry make some utilisation of the dissolved humus-substances possible.

Leaving the question of the origin of peat aside for the moment, we must notice what an extraordinarily thick deposit it sometimes makes. We see this very well where the peat-cutters have been at work. It is often six feet deep; it may even attain, Professor Schimper says, to a thickness of thirty feet. This means that the mineral substratum is at a great distance from the surface. *Thus the second difficulty in the high moor is the scarcity of mineral salts which plants need as part of their food.* In the meadow moor the layer of peat is comparatively thin and the proportion of available mineral salts is much greater.

All living matter consists in part of complex nitrogenous carbon compounds called *proteins*, and it is therefore imperative that living creatures obtain nitrogen supplies in their food. The difficulty on the high moor is to get these supplies. There is abundance in the peat and in the peaty water, but it is not in available form. The nitrefying bacteria which usually change nitrogenous substances in the soil into available form will not thrive on the moor. The nitrogen-capturing bacteria which make tubercles on the roots of leguminous plants and help them to thrive in poor soil by somehow fixing the nitrogen so abundant in the atmosphere appear to object to a peaty environment. Nor do earthworms thrive in peat. Professor Bottomley has been trying of recent years to cultivate a microbe that will make peat available as a soil for plants. If that is accomplished it will be a great achievement.

But there is one kind of plant that thrives on the high moor—the plant that has made the moor what it is: the Bog Moss, or *Sphagnum*. It grows in great spongy cushions, which are always dying away below into sphagnum peat, and rising higher in the centre. Sometimes they die in the middle and grow bigger and bigger round the circumference. The tendency of the high moor as a whole is to become convex, and it is to this bulging that the technical term refers.

There are different kinds of Bog Moss, and the colours are often varied, but all agree in their great capacity for absorbing water. Enclosed by cells containing the green chlorophyll there are water chambers, usually stiffened with fibrous thickenings and communicating with one another and with the exterior by round pores. These water chambers form a continuous system of capillary tubes throughout the plant, and allow much water to be stored. There is also a sort of external storage in the fine capillary spaces between one leaf and another. There are two ways, then, in which the Bog Moss acts as a very efficient sponge.

Now the crucial question arises: *What water?* It seems that almost all the water which you can wring out from the Bog Moss sponge has come from the air in the form of rain and mist. It has not been absorbed, except in very minute quantities, from the wet soil; indeed, the soil-water seems to be poison to the Bog Mosses. We suppose that enough soil-water is absorbed to give the Bog Moss a small quantity—the indispensable minimum—of nitrogenous salts; but perhaps there is something here awaiting discovery. It must be admitted, of course, that the living matter of Bog Moss is, so to speak, very thin. Apart from the non-nitrogenous (cellulose) framework of the plant, there is not a great deal more than animated rain!

In recent years we have come to know the value of "moss" in hospitals; it is so deliciously soft, and it can absorb like a sponge. But we must not forget the incalculable importance of these great beds of Bog Moss on the moorlands and at the foot of the hills. It is because of the Bog Moss sponges that the rivers continue to flow. From the Bog Moss come many of the runlets of water which feed the rivulets which form the streams which make the rivers.

The making of the peat is going on still, and no plant helps more than the Bog Moss. What is it that happens? The firmer dead parts of the plants, bathed in stagnant, airless water, undergo a peculiar change. It is not like ordinary rotting, which requires the active intervention of bacteria. They change into carbon compounds with little oxygen, and they may finally become pure carbon. The membranes and fibres of a carpet of vegetation become pressed together and form peat, in a compact crust which does not mix with the underlying mineral layers. These, indeed, are eventually several feet below. It may be said, then, that peat is made of the fibrous parts of plants which have undergone very incomplete rotting; it is slightly aerated and rich in brown ulmic acid and blacker humic acid; it is very spongy, and does not let the water through as vegetable mould does; it dries very perfectly on an exposed slope, but it becomes heavily waterlogged when the evaporation or seeping away of the water is slow. Peat seems to be restricted to the colder parts of the globe, for its formation implies slow and partial decomposition in presence of abundant water. The browner it is the less decomposition there has been, and the better it will be for burning. While peat is mainly due to Bog Mosses and other bog plants, it may be formed to some extent when a forest has been cleared away and when the ground becomes too *dry* for earthworms. The accumulation of vegetable matter may continue for a time and form a peaty crust—the forest turns into a dry heath. Later on some subsidence or blocking of drainage may turn the heath into a peat bog.

Cutting the peat year after year does not necessarily put an end to the supply, unless the peat-cutters are too greedy. For more peat must always be made. What is likely to put an end to peat formation is drainage, especially if that means the introduction of water from a surrounding area. But as long as a big hummock of Bog Moss keeps a lot of stagnant water about it like a sponge, the oxygen in the water is not replaced, and peat formation sets in.

In order to understand better what peat is *not*, a little must be said in regard to soil-making in general. The weathering of the rocks may be said to produce *earth*, but this requires to be mixed up with the results of the decay of plants (and animals too) before it is worthy of the name of *soil*. Even very simple plants, such as Algæ, Fungi, and Lichens, help a little in this soil-making, which one can recognise by the colour of the earth becoming darker. One sees the beginning of this even at the top of the mountain.

When the leaves of plants fall to the ground in a shady wood, or in any place, not very dry and not very wet, where earthworms are abundant, the formation of vegetable mould begins. The earthworms swallow the decaying parts of plants along with the earth, and they digest part of the vegetable matter. The undigested and indigestible stuff is voided on the surface in the form of worm-castings, and thus fertile soil is made. There are many processes going on at once: the vegetable matter is changed into more available form and it is intimately mixed up with earth, the soil is made to circulate in its surface layers, and it is ground to powder in the gizzards of the earthworms, the burrows make and keep the surface soil looser, opening it up to the air and the water.

The result all over the world has been the formation of vegetable mould—loose, richly aerated, and not sour.

The reasons why peat is not really soil are that it has not been sufficiently mixed up with mineral materials, that its nitrogenous components are not in an available form, and that the abundance of organic salts (when there is little lime) acts as a plant poison. It is a useful fuel, it has not become a soil; it has not been sufficiently worked on by bacteria or by earthworms. Only in the transitional meadow moor, or where the farmer has put brains into the using of it, do we see peat entering again in the cycle of life by becoming part of the soil.

Perhaps we may be allowed to say that a little reasonable care is needed in exploring peat bogs, for there are treacherous surfaces which yield under the feet and may involve the unwary in a dangerous quagmire. It is risky to begin jumping quickly from hummock to hummock, for one comes a cropper before long. As the Italian proverb has it, he who goes slowly goes far. Of course for a bog excursion one should put on old clothes and either very old or thoroughly waterproof boots.

Very conspicuous in moist places, sometimes on the black sides of the bog ditches, are the squat, fleshy leaves of the Butterwort, which suggest the arms of a yellowish starfish. The technical name *Pinguicula* means "Little Fat One," and the plump leaves certainly look as if the plant flourished well. Part of the secret is disclosed when we look at the number of small midges and other insects on the glistening leaves, for the Butterwort is a carnivorous plant. It is not difficult to cut off the skin of the leaf with a razor and see under the microscope that the glistening appearance is due to numerous toadstool-like glands making a clear digestive fluid. The inturning of the margins of the fleshy leaves also helps in the capture of the insects, which are first digested and then absorbed. It is worth while taking a leaf of the Butterwort and putting it into a test-tube with a little milk, for then one sees that the milk curdles, which is due to an acid accompanying the digestive juice. When we remember that the digestive juice in our own stomach is also accompanied by an acid we get from this common peat-bog plant a glimpse of the deep sameness of the processes of life in all kinds of living creatures. It is interesting to know that the shepherds sometimes press the leaves of the Butterwort against the udders of the Sheep when these become sore; we suppose that the digestive juice on the cool leaves will help to clear away microbes. We must not leave the Butterwort without recognising the great beauty of its violet flower, which is seen in late summer.

More attractive than the Butterwort are the Sundews (*Drosera*), with their beautiful red leaves spread out on a cushion of Bog Moss. Each leaf is shaped like a flat spoon with a long handle, and round the margin of the broadened end there are delicate tentacles, the tips of which bear glistening drops of what looks like dew. For this reason in many languages this interesting plant is called Sundew. The drops are not of dew, however, but of digestive juice, for the Sundew, like the Butterwort, is carnivorous. It is interesting to see a small insect caught on a tentacle, to watch the touched tentacle bending in on it, and to verify the fact that the news spreads to neighbour tentacles which come to help. By and by, as Darwin said, the Sundew leaf is like a closed fist, and the insect is pinned down upon the centre of the leaf. If a microscope is available it is not difficult to put the leaf on a glass slide with a big drop of water and to lay a cover-slip over it, so that one may see something more of the wonderful hairs which have been changed or evolved into tentacles. If a little trace of very dilute ammonium carbonate be allowed to enter under the cover-slip one has often the pleasure of seeing a change travelling down the tentacle, for the tentacles are sensitive almost beyond telling to any nitrogenous substance, such as ammonium carbonate, or the least trace of beef-tea.

It cannot be a coincidence that there are so many Butterworts and Sundews on the boggy ground. This is another example of the kind of riddle that rewards. These carnivorous plants grow in places, such as peat bogs, where the soil has little in the way of nitrogenous salts. Indeed, some of them, like the Pitcher Plants, live off the ground altogether. The carnivorous habit, which is like the plant turning upon the animal, is an adaptation to a poor supply of the absolutely essential nitrogenous food-supply—absolutely essential, as we have already mentioned, because all life depends chemically on the breaking down and building up of proteins, which are very complex nitrogenous carbon compounds. When plants cannot get nitrogenous food-supplies from the soil they must get them somewhere else, and one of the ways is to capture insects, for their bodies contain much protein material.

The vegetation of the high moor may include the Common Heather, the Cranberry, the Cowberry, the small shrub called Andromeda which is a member of the Heather family, the delicate little Milkwort (*Polygala*), and some Sedges. There is also the handsome tall Cinquefoil (*Potentilla comarum*), with purple-brown stems over a foot high and with purplish flowers. Its rootstock yields a purplish dye. Very characteristic of bogs is the Lousewort (*Pedicularis palustris*), a leafy annual with a stout, rather fleshy stem that grows to a height of six to eighteen inches and bears dull pinkish flowers. It has a strange appearance of prosperity; it looks too well-to-do for these places, where it is hard to find a living. Such suspicions are well grounded; the plant is a thief. It attaches its roots into the roots of neighbouring plants and sucks nourishment from them. The name "Lousewort" refers to the idea that the plant gives the Sheep lice, the fact being that sheep fed where there is little to eat become weak, and weakly animals tend to have parasites.

On the outskirts of the bog and on drier islands here and there there is often abundance of Bog Myrtle or Sweet Gale (*Myrica gale*), which is very characteristic of the meadow moor. We cannot pass it without an appreciation of its aromatic fragrance, so pleasant when we press the leaves between our fingers, and finer still when it steals into the air like frankincense. The scent seems to be due to an ethereal oil, a sort of by-product of the plant's living. From the leaves the cottagers used to "brew" a potent medicinal tea.

Very characteristic is the Cotton Grass (*Erio-*

phorum vaginatum), whose white flags are so conspicuous in late summer on the boggy moors, up to a height of nearly 3,000 feet. It is not a Grass, but a Sedge, one of the Cyperaceæ—a family including many frequenters of swampy ground, one of which furnished long ago the papyrus that came before paper. The Cotton Grass is a perennial plant, whose presence always indicates the need for drainage or the difficulty of effecting it. The flower-stalk rises about a foot from the ground and bears a tuft of spikelets. Round the base of each of the flowers of the spikelet there are numerous bristles which afterwards grow long and become the beautiful white "cotton" of the fruit. The wind carries the pollen from one flower-head to another, and the wind scatters the three-cornered nutlike fruits to which the cotton forms a parachute.

Only three others dare we mention. On the sides of the ditches of a peaty bog near the sea we have often found the perennial Bog Pimpernel (*Anagallis tenella*), first cousin of the annual Scarlet Pimpernel, or Poor Man's Weather Glass, of fields and waste places. The finely veined rosy corolla of the Bog Pimpernel seems to us the most delicately beautiful flower in Britain. In bogs, from sea-level to a height of 1,000 feet, the Marsh Pennywort (*Hydrocotyle vulgaris*) flourishes, with a white threadlike creeping stem, with leaves like circular shields, and pinkish-green flowers, so small that they are difficult to find.

One of the finest of the Saxifrages is the Grass of Parnassus (*Parnassia palustris*), characteristic of bogs from the sea-level to a great height. There is a solitary white flower (occasionally yellow) on a long stalk, which gives forth a fragrance of honey during the day and is scentless at night. There are five stamens and when one is quite ready to allow the pollen to burst from its anther it is incurved to the centre of the flower. An insect alighting from above on the centre of the flower is sure to get brushed by the bursting anther, and if an insect creeps in from the margin of the petals it has to surmount a curious fence of filaments radiating from the nectar-producing scales. In getting over this fence the insect is brought near the centre of the flower, where the bursting stamen is, and is sure to be dusted with pollen. When a stamen has lost all its pollen it curves outwards, and another moves in to take its place, till all the five are emptied. Then, since they have all curved outwards, the pistil is left clear. Now as the pistil ripens later than the stamens it must be cross-fertilised by pollen brought by the visitors from another Grass of Parnassus flower which opened a few days after the first. This subject may be pursued further in the great treasure-house known as Kerner's "Natural History of Plants," translated and edited by Professor F. W. Oliver.

Another very pleasing flower, especially common in wet places, is the Bog Asphodel (*Narthecium ossifragum*), which belongs to the Order of Lilies. From a long wiry creeping stem, with stiff, sword-shaped leaves, there rises an erect and stiff flowering stalk. The flowers appear in July and August and have a charming golden-yellow colour. As the dry perianth persists around the red seedbox, the fruiting Bog Asphodel looks as if it were still flowering. This lends great beauty at the end of summer to many bogs. The Bog Asphodel is able to secure its own pollination without requiring the help of insects or the wind.

The moor is still a feast of colour in early autumn—the Heather and the Heath, the Hare Bells and the Silver Weed, the Centaury and the Viper's Bugloss; but there is no more striking colour than the bright red of the Fly Agaric, or Fly Toadstool (*Amanita muscaria*), growing under the Birch-tree. The colour is very pleasant, but the flesh is very poisonous; it was once used in making fly-papers. On the red umbrella (disc or pileus) there are whitish scales and others at the swollen base of the white stalk; these are the remains of the loosely felted envelope or wrapper which protected the young Toadstool when it was developing beneath the ground. We can see this on the small knobs which are just emerging. As the Toadstool proper grows and the disc or umbrella broadens out the white envelope is torn into rags. The young globular heads of many Toadstools have the under surface of the disc enclosed in a membrane, or "velum," which stretches out from the stalk to the circumference of the disc; and as the disc grows this veil is broken, leaving a residue in the form of a down-turned collar towards the upper end of the stalk. This is plain on the cultivated Mushroom (*Psalliota campestris*) and in many other cases. It is interesting to get several specimens showing the Toadstool's changes of shape: the globular head becomes umbrellalike, and this in turn becomes upturned round the margin so that the upper surface is almost flat or even concave. This exposes the spore-producing plates or "gills" and allows of the scattering of the dust or spores. The whole Toadstool is a spore-making "fructification," growing from branching threads (the "spawn" or "mycelium") spreading in the soil and feeding on decaying vegetable matter. When the spores are scattered and fall into crevices, they grow into the white threads, which start more Toadstools. It is necessary, however, to go back for a minute to the bright red Fly Agaric. The gills are not formed quite in the usual way; they arise as radial plates in the feltwort *inside* the young dome-shaped head, not as *free* downgrowths as is usual in Toadstools of this type. The radial plates are shut in by a felted membrane connected with the stalk; this gets broken when the disc expands; and the remains of it form a down-turned collar round the upper end of the Fly Agaric's stalk. We mention this because the collar here is different from the collar which we have already spoken of on the Common Mushroom.

There are oases in the moor where some clearing and some differences in the soil or in other conditions have allowed of the growth of thick short grass. Sheep and Rabbits have sometimes helped to make these pleasant spots. We know of one that is surrounded by high juniper-bushes making a screen from the wind; the sward is like velvet; it seems like enchanted ground—a dancing-place for Titania and her fair retinue. In such places, as well as on the close-cropped links, there are often fine "fairy rings" which may last for many years, becoming gradually larger. A ring, sometimes perfect, sometimes broken, is seen in the grass; it is different in its shade of green from its surroundings. Sometimes we have seen not a ring, but a solid circle, so to speak, with the grass thicker and greener than beyond its bounds. The explanation of fairy rings is not difficult. One starts with a stalked Fungus like the Common Mushroom, which is so palatable, or with the Fly Agaric, which is so poisonous. Both are common causes of fairy rings. The spores are scattered in a circle around the original clump; they sink into the soil and form an underground circle of spreading white threads. These are practically perennial and extend outwards into new territory. They may also give rise to more Mushrooms or Fly Agarics, which produce more spores; and as these are scattered and develop the ring of white threads expands. Now the white threads (technically called "hyphæ") which branch in the soil absorb some of the organic matter of vegetable mould, and supply the above-ground parts with all their food; they exhaust the available materials, so that for the time being no more threads can develop there; the scattered spores will develop only in the unexhausted soil to the outside of the spreading ring. So the ring is formed, the difference in the colour of the grass being an index to the influence of the white threads, or Fungus "spawn." That influence is interesting. One might think that the use the Fungus makes of the rotting vegetable matter in the soil would tend to impoverishment, but green plants do not use the organic materials in the soil directly, nor until they have been changed into salts like saltpetre. The spreading threads make some of the organic materials in the soil more available, and when they die away in the soil which they have exhausted and push on into fresh soil, their decayed parts are left behind and are said to be very stimulating to the grass.

It might be objected that the above-ground growths—the Mushrooms, for instance—are fed from the soil through the food-absorbing hyphæ, and that if the Mushrooms are devoured by a Snail, that means a final loss to the soil. But two points should be noticed: that the above-ground growths contain a large percentage of water, and, second, that the Snail must return part of what is eaten to the soil, and that when the Thrush that eats the Snail is killed, perhaps, by a very severe frost in winter, and is rotted away on the ground there is a bigger return still.

The idea of the circulation of matter, already alluded to in our studies, is fundamental. The growing green plants which have used the power of the sunlight to build up out of air, water, and salts such complex substances as sugar, starch, and proteins, come in the course of time to an end, or it may be that they only shed their leaves. The withered parts are taken beneath the ground by earthworms, and parts of them become food for the white threads of the Mushrooms, which, having no green pigment, or chlorophyll, are unable to build up organic compounds for themselves. The activity of the white threads results in the material of the above-ground Mushrooms, and in substances which stimulate the growth of Grass; and parts of the white threadwork are always rotting away. The Mushrooms are eaten by the Snail, and the Snail by the Thrush, and from both there may be a return of materials to the ground, to enter again into the magic circle of life. For thus the world goes round.

We cannot leave the moorland without two notes. First, we have only nibbled at it. Just as there are different kinds of heath so there are different kinds of moors. And in an upland moor it is often possible to distinguish different zones, each with its own character. Thus botanists distinguish—(1) the Bog Moss association, (2) the Cotton Grass association, (3) the association marked by a characteristic Sedge, called *Scirpus cæspitosus*, (4) the Bilberry association, and (5) the Heather moor. The arrangement of these indicates a gradually decreasing amount of soil-water.

The important general idea that we have tried to make clear is this: that in a considerable variety of habitats, which may be called moorland, there is sour soil, abundant in humus acids, poor in usable nitrogenous compounds, apt to be wet, cold, and badly aerated. The practical result is that though water may be abundant it is not abundantly available. The particular fitness to meet this is to economise transpiration, and there are many different ways of effecting this. In his "Œcology of Plants" (1909), Professor Warming mentions, for instance, a well-developed coating of hairs, as in some Willows, waxy incrustations, as in Cranberry, thick cuticle, as in *Scirpus cæspitosus*, thick skin, as in Cowberry, the shutting in of the stomata so that the water vapour escapes with difficulty, as in Ling and Bell Heather, the reduction of leaves, as in Rushes, and sword-like leaves, as in Iris and Bog Asphodel.

Second, none of the types of vegetation is permanent; all are in process of transition. In many cases, the stumps of trees among the peat show that what is now a peat bog was once a forest. In many cases under our eyes the peat bog is passing. Messrs. Lewis and Moss discuss the degeneration or retrogression of the moorland in Mr. Tansley's "Types of British Vegetation." In times of drought the beds of channels among the peat become more or less dry; the banks crumble; the wind removes dust; the channels are widened. Rain-storms come, the channels are flooded; large quantities of peat are carried away; the streams cut back into the peat plateau and wash down to the rock below. Tributary streams and networks of channels are formed; the peat moor is "divided up into detached masses of peat (known as 'peat hags'), and the final disappearance of these is only a matter of time." All things flow, peat bogs and all.

The destruction of trees by man, by fire, by wind, and other agencies, may involve (1) a loss of the characteristic vegetation on the ground of the forest, (2) an accumulation of raw humus, (3) a disappearance of earthworms, (4) an invasion of the area by Ling, and so on. But happily there is the possibility of more hopeful successions. The careful draining of the moorland, the letting in of water rich in certain salts, the use of lime, and other expedients, may reclaim a Heather-covered tract into the service of man. Professor Warming writes: "Even one year after the commencement of irrigation Ling vanishes, and after a lapse of three years the Heath may be replaced by a carpet of Grass, and the soil may be inhabited by earthworms" ("Œcology of Plants," 1909, p. 363).

CHAPTER VII

THE FAUNA OF THE MOOR

The Red Grouse—The Curlew—Stonechat and Whinchat—The Adder—The Slow Worm—The Tiger Beetle.

Apart from Birds and Insects the moor does not show much of its animal population to the casual onlooker. There are two main reasons for this: the Heather and similar thickly growing plants make excellent cover, and many of the moor animals are of small size. But there is another reason, that many animals are given to effacing themselves; they are shy and fond of hiding; they lie low and say nothing. This is true of a large number of animals in all sorts of places; it holds good on the moor. The useful technical word "cryptozoic," which means "of hidden life," is applied to those animals that live very quietly or possess the secret of the Gyges ring, which made its possessor invisible.

It is impossible for us to take account here of the small animals of the moorland. There are Thread-worms eating the decomposing vegetation and sometimes squirming up the wet stems of the Heather; beautiful wheel animals, or Rotifers, often found about the Bog Moss; sluggish bear animalcules, or Tardigrades, among decaying leaves; and it may be noticed that all these are able to survive drought by sinking into a mysterious state of latent life until the rains return. There are Water Mites in damp places, and here and there, in a pool with Water Fleas and other minute animals in abundance, we may be fortunate enough to find the true Water Spider (*Argyroneta natans*), which spins her web under water and there brings up her family. Among the Heather there are numerous Spiders, all keeping to dry land, some making rough-and-ready snares and others finely constructed webs. Some lay their eggs in a silken cradle attached to the Ling, others carry them in a silken bag or cocoon, held below the front of the body. There is great variety of insect life—Moths and Butterflies, Ants and Bees, Gnats and Midges, Beetles and occasional Dragon Flies; and there are a good many different kinds of Snails creeping slowly about. One comes across an occasional Frog enjoying the insects in its quiet way, and sometimes a Toad, a Newt, a Lizard, or an adventurous Vole.

This is not the place for lists, though it is useful to make mention of a few examples of the moorland animals; but it must be understood that they are not more than samples, which the explorer should amplify and extend.

We associate certain sounds with certain places, though the associations different people form may vary considerably with individual experience. When we think of the Lark's song we see the links; when we think of the Oyster-Catcher's shrill "Keep, keep" we see a great stretch of gravel by the side of the river or the boulder-strewn beaches of the restless sea; when we think of the cawing of Rooks we see the tall trees; and when we think of the warning "Kok, kok, kok," which the male of the Red Grouse utters, we see the Heather-covered moorland.

The Red Grouse (*Lagopus scoticus*) is confined to the British Islands and to places where it has been introduced in recent years. It is a native of this country, and of no other; which means that its kind arose in these islands from an ancestral stock common to it and to the Ptarmigan (*Lagopus mutus*) and the Willow Grouse (*Lagopus albus*). We may see the same sort of thing happening on a small scale to-day in the origin, for instance, of a distinct race of Wren in the islet of St. Kilda and of another in the Shetlands. A new departure or variation crops up, and if its peculiarities are of such a nature (1) that they are readily handed on or entailed in heredity, and (2) that they are well suited to the conditions of life, then a new race may begin.

The Red Grouse is well represented in some upland heaths of the North of England, on many Welsh moors, and throughout a large part of Ireland; but it flourishes best in Scotland. It is a good example of a thoroughly resident bird, keeping consistently to its own place, except that it comes to lower ground in severe wintry weather, or even leaves the district if things are quite hopeless. The food consists very largely of the tips of the twigs of Ling and Heath, Crowberry and Blaeberry, besides, in autumn, the seeds of Sedges and Grasses, and such small berries as may be available. It seems that the young birds require more digestible food—namely, small insects, which the parents help them to find. According to Mr. Abel Chapman, Red Grouse burrow beneath the snow in winter and thus get at supplies of growing mountain plants.

The cock bird is predominantly ruddy, while the hen shows more of a yellowish-chestnut tint; but the description of the colours of the Red Grouse is very complicated. Thus from June till October the male, having moulted his fine breeding plumage, wears an "eclipse" suit, which resembles the breeding plumage of the female. The pairing takes place early in the spring and, unlike the Black Grouse, the Red Grouse does not try to get more than one wife to bear him company. The hen makes a mere apology for a nest in the shelter of the Heather, and sits very close for over three weeks on from seven to twelve reddish eggs. No brooding is done by the cock, but he keeps watch and utters his loud hoarse alarum on very slight provocation. There is a good deal of casual fighting among cocks who meet one another on the moor. The young birds are very precocious, being able to run about soon after they leave the egg. There is great mortality, however, in the early months, for the moorland is a hungry place.

There is much that is very interesting in these familiar birds. The naked skin above the eye forms a warty ridge of a red colour; the pigment that causes the redness is called "zoonerythrin" (which means "animal-red"), and it is the same as we see in the Flamingo and the Cardinal Bird. Moreover, it seems to be almost the same chemically as the red pigment of the shell of the Norway Lobster and of many other crustaceans.

Instead of the scales that occur on most birds below the ankle-joint and on the toes—scales that betray the bird's affinity with reptiles—there is in the Grouse a thick stocking of feathers going down as far as the claws. And in regard to the claws it is interesting to find that they are moulted late in autumn, the worn sheath slipping off and disclosing a fresh growth well suited for all the scratching for food that is required in winter. Just as the Puffin moults annually the outer covering of its quaint bill, so the Grouse moults its claws, and in so doing both birds are, so to speak, declaring their distant relationship to reptiles, which periodically cast off the outer layer of the skin which covers the scales.

In his enquiry into grouse disease (1911) Sir Arthur Shipley found that there were eight different kinds of insects and mites living on the outside of the Red Grouse and no fewer than fifteen different kinds of parasites living in the interior—unpaying boarders. Two of these are especially important: a transparent Threadworm that frequents part of the food-canal (there may be 10,000 in one bird), and a microscopic single-celled animal, called Coccidium, which lives in countless numbers in the wall of the food canal in young Grouse. Now the young stages of the minute Threadworm are found squirming among the leaves of the Heather, and it is by eating the heather that the Grouse is infected. The other side of it, however, is that the Heather is externally infected with the Threadworms by droppings from the Grouse. These contain eggs which hatch in a couple of days into microscopic worms, which after resting for a while become active wanderers, ascending the Heather and other plants, especially after rain. When Grouse are in vigorous health it seems that they can tolerate, as many other living creatures can, a considerable contingent of parasites. A sort of "live-and-let-live" partnership is established. But the Grouse may get out of condition, because of persistently bad weather, or because of lack of food, or because the stock has deteriorated through the survival of weakly birds that the Golden Eagle and other enemies would have sifted out if Man had not interfered. If there is a deterioration of vigour and resisting power, then the unpaying boarders inside the bird may begin to get the upper hand and do serious damage. The cock-Grouse seem to fall victims much more readily than the hens. And then it is that we say "grouse disease." This, at least, is one view of a difficult problem of the hills. We are probably safe in saying that a removal of the enemies that sift a wild race of animals by cutting off the less vigorous and effective is likely to be to the detriment of that race. We are probably safe in saying that constitutional disease is practically absent in wild nature, for if it appears it is promptly nipped in the bud. We are probably safe in saying that the customary parasites of an animal are not in ordinary cases of deadly importance, but that they may become so if the creature's natural vigour or its ability to keep itself clean and fit is weakened. What is apt to be very serious is when animals become infected by a new kind of parasite, to which they are utterly unaccustomed. This is what happens when horses, for instance, are bitten by a tse-tse fly in Tropical Africa, and thereby infected with an invisible trypanosome, first cousin of the one which causes sleeping sickness in Man. But it seems that various wild Antelopes have trypanosomes in their blood without being much the worse; they have established a compromise with their parasite.

Another sound very characteristic of the moorland is the cry of the Curlew (*Numenius arquata*), or Whaup. The bird is also fond of the seashore, especially in winter; but its nesting-place is on the moors, both high and low. It is easily recognised among other waders by its large size (two inches over two feet in length) and by its long curved bill, which, by the way, is quite short when the young bird is hatched. The brown streaked plumage often harmonises well with the surroundings, notably when the Curlew is brooding among last year's withered ferns and herbage. The nest is hardly more than a depression made comfortable with grass; and the four large, greenish and brownish, broadly pear-shaped eggs lie with their points towards the centre. They are usually laid about the end of April or the beginning of May and have to be brooded on for about a month. The young birds feed chiefly on insects and their larvæ; the adults eke out this diet with earthworms, slugs, and small juicy fruits (such as those of Crowberry and Bramble); in the winter they eat almost any little animal that they can get on the sand, or on the mud-flats, or among the rocks. The flesh of the Moor Curlews is palatable, but that of the Shore Curlews is rank.

The Curlew is wide awake and wary, but the brooding bird will sometimes sit close instead of flying from the nest. We have known one allow the photographer to come within a few feet of her. Both parents are brave in defence of their young ones, and will even stand up to a Raven. There is much to be learned about the intimacies of the Curlew by any patient observer who is clever enough to get the better of the bird's shyness.

One of the most interesting things about the Curlew is the courting flight, which we have often watched in the Easter holidays on the Deeside hills. The male bird soars to a considerable height in the air and hovers; it sinks and rises again; it circles and hovers again; and all the time it pours forth a simple trilling song, certainly not plaintive, singing over and over again—"Courlie, courlie, courlie." This is very different from the rather mournful "Whaup, whaup" of the winter season.

Very like the Curlew in most ways is its much smaller cousin the Whimbrel (*Numenius phæopus*), but it usually breeds much farther north than Britain. It is a well-known visitor, however, to our shores, chiefly as a bird of passage, and the rippling whistle, often seven times repeated, is a delight. To this the name "Seven Whistler" refers, and "Titterel" is also suggestive. Mr. Masefield says:

> "And like the shaking of a timbrel
> Cackles the laughter of the whimbrel."

There are two other birds so common on many moorlands that we must take note of them: the Stonechat and the Whinchat. They are first cousins, two species of one genus. The Stonechat (*Pratincola rubicola*) is for the most part a resident, and the male is easily recognised by his black head, white collar, and ruddy breast. He flies from one whin bush to another, selecting the topmost branch, and uttering a scolding note, and jerking his tail. Both parents say "Chack" when anxious about their nest. This is made on the ground, hidden among rough herbage or at the foot of the whin bush; it is composed of grass and moss to the outside, feathers and hair within. The Stonechat is almost wholly insectivorous.

Stonechats have been described as irascible, and they certainly leave one in no doubt as to what they think of a prying intruder. The hen sits very close; the male is a good husband and father. The young ones remain long in the nest and require large quantities of Flies, Caterpillars, Spiders, and so on. The parents, Miss E. L. Turner notes, sometimes bring food twice a minute; and Mr. Farren reports twenty visits in fifty minutes. Careful observers of birds are among the few who have anything like an adequate idea of the amount of time and energy that is often devoted to other-regarding activities.

The Whinchat (*Pratincola rubetra*) is a summer visitor, arriving in April or May, leaving early in October. It frequents heaths and moorland like the Stonechat, but the two cousins are seldom much together, and the Whinchat has a fondness for pastures. As regards nest, eggs, food, call-note, and song, the Whinchat is not very different from the Stonechat, but the adult male has a dark brown head, with a long white streak above the eye, and a fawn-coloured breast. The general colour of the upper parts is brown and buff, very inconspicuous in the bird's ordinary habitats.

Whinchats are more elegant birds than Stonechats, less brilliant in colouring, but not less subtle. The nest, though generally like the Stonechat's, is lined with fine dry grasses. Miss Turner writes in Kirkman's magnificent "British Bird Book" (vol. i., p. 417): "The Whinchat's song is a short warble, often repeated, sometimes for half an hour at a stretch.

The bird usually remains perched on a twig, or swaying to and fro on some umbelliferous plant, but sometimes he sings on the wing. He is never in a hurry like the Stonechat or Wheatear, though now and again he will break off in the middle of his song, dart into the air, seize some winged dainty, return to his perch and begin the song all over again. Few birds, if any, seem able to catch up a strain where it was broken off, but have to start afresh—a striking instance of conventionality in beings so erratic by nature."

It seems just to call the Adder (*Pelias berus*) characteristic of the moorland, although it also occurs on commons and in woods. We have seen one sunning itself on a bed of wild Thyme by the roadside where cutting off an elbow had made a big heap of stones and gravel; we have nearly trodden on one lying on a narrow sheep-path more than half-hidden by the Heather. In general, Adders may be said to like dry and warm places, where there is not much traffic of men or of larger animals. For they are shy creatures, depending on small prey such as young Mice and Voles, Frogs and Newts, and it is entirely unprofitable for them to waste their venom on Sheep, Dog, or Man. As a matter of fact, they are in the main nocturnal in their hunting, though they are fond of resting in the sunshine. They have very few enemies (except Sheep, which stamp on them), and this fact, taken along with their elusive habits and their occurrence in places where escape is easy, may help to account for the great variety of colouring—grey, brown, olive, red, black—for it has not paid the race to adopt any fixed hue. In many cases there is a St.

Andrew's cross of black or dark brown on the top of the head and a zigzag dark band along the middle line of the back. An Adder two feet long is a large specimen.

There are many facts about the Adder that are significant from our general natural history point of view. It is the only poisonous snake in Britain, the Grass Snake (*Tropidonotus natrix*) and the Smooth Snake (*Coronella lævis*) being quite innocent. As it is widely distributed throughout Europe and yet does not occur in Ireland, the probability is that it colonised Great Britain after Ireland had been separated off, and while the land connection between Great Britain and the Continent was still in existence. That there should be so few snakes altogether in Britain is to be connected with the fact that they are coldblooded animals, tending to take on the temperature of their surroundings and thus ill suited for countries that are very cold in winter. The Adder has a constitution well suited to stand cold, for it is found on the Alps up to 6,000 feet; but, whether on mountain or low ground, it passes into winter lethargy for a variable number of months according to the severity of the conditions. It sinks into a state of "suspended animation," and the risks of the cold are lessened by the reduction of activity to a minimum. We think it useful to keep the term "hibernation" for the winter sleep of Mammals, which are warmblooded; but the winter lethargy of the Adder illustrates the same general policy of evading danger by "lying low and saying nothing." In their winter retreats, in a rabbit's hole, it may be, or in the middle of a heap of rubbish, large numbers are often huddled together.

The pairing takes place from March to May, and the young ones are born in July and August. We say "are born," since the Adder is not an egg-layer like the Grass Snake, but viviparous. The telescoping of the development of the young ones so that it takes place within the safety of the mother's body is often an indication that the life of the young is precarious, especially if they are helpless to begin with.

The Adder's bite—what does it mean? The fangs are formed by a pair of long, curved, tubular teeth, borne by the movable maxillary bones; the tube is open at both ends; at the base it is in temporary connection with the duct of the poison gland (which turns out to be a transformed salivary gland). The poison passes from the compressed poison gland along the canal of the tooth and escapes through a minute groove towards the tip of the tooth. When the Adder gets its fangs into the Mouse or other victim, a little of the poison is automatically injected into the wound, and this paralyses and kills with great rapidity. The fangs are apt to be broken, and in any case they only serve for a limited time; there is a succession of reserve fangs ready to replace them. When a new fang moves into the vacant place its base has to be connected with the duct of the poison gland.

One of the most elusive creatures of the moor is the Slow Worm (*Anguis fragilis*), a limbless lizard of most innocent qualities, which unthinking, stupid, or cruel people often kill. Its fatal resemblance to a Snake is quite superficial, and is simply a shape likeness, due to both animals being adapted to creeping through holes and among herbage. Almost all Snakes except the burrowers have got a single row of large scales on the ventral surface of the body; these grip the ground when they are raised by the under-skin muscles, and they enable the ribs, moving backward and forward, to row the body along. In the Slow Worm the body is covered almost uniformly with roundish overlapping scales, with small bony plates beneath them, which are never found in Snakes. Although the creature is often called a Blind Worm (which does not say much for observation), it has well-developed eyes, with yellowish-red iris and with movable lids, whereas in Snakes the upper and lower lids are mere vestiges, and the third eyelid seems to have bcome fixed as a transparent blind across the non-movable eye. Thus the Slow Worm has not the "stare" of the Snake. Moreover, although the opening of the ear is a very small pit in the Slow Worm, there is an opening, which is more than can be said of Snakes. Finally, if a Slow Worm is a foot long, about half of this is tail, whereas that part of a Snake's body is comparatively short. Internally, the two kinds of reptiles are not in the least like one another. We have given part of the answer, then, to the very reasonable question: Why is a Slow Worm not a Snake?—a question which is not a conundrum, but a useful enquiry into the differences separating two creatures which are superficially a little like one another, having been similarly adapted to similar conditions of life. This kind of adaptive resemblance is often called "convergence."

The colour of the Slow Worm is variable, but on the whole it is brownish above and darker below. The newborn young ones are silvery above, with three black lines, and black below. Over the scales there is, as in other reptiles, a thin layer of epidermis, which is shed or moulted periodically. It is polished in the Slow Worm and is shed in flakes, whereas in Snakes it comes off all in a piece as the "slough," which is turned inside out from the head backwards.

On the top of the skull there is a tiny mark which indicates the position of a remarkable body, the parietal organ, that grows upwards from the brain in many backboned animals. In the New Zealand "Lizard," Sphenodon, which is the only surviving representative of a lost race, the parietal organ has distinct traces of being an eye, and there is some hint of this in the Slow Worm. It seems to be a sense organ, and some have suggested that it has to do with feeling changes of temperature.

Slow Worms hunt on the moor during the day, seeking for Earthworms and Slugs, Insects and Spiders, and other small animals. They catch them in their fang-like teeth. Neither young nor old like the glare of the sun, but warmth seems to be appreciated, and one sometimes gets a glimpse of a full-grown Slow Worm basking curled up on a bank. A glimpse is all one usually gets, for the Slow Worms seem sensitive even to a shadow. When frightened they glide very quickly into shelter, among loose stones or into a hole or among the herbage and moss. In such places they also pass the night. When winter comes they burrow into the dry ground, being careful to select a well-drained, sunny, and secluded spot. A number of them are found in the same winter quarters, lying close together in a lethargic state corresponding to the hibernation of some Mammals.

The young ones are born in August or September, about a dozen in a litter. One hardly knows whether to say born or hatched, for the transparent, yellowish egg envelope is burst just as each egg is laid. This liberates a fully formed miniature Slow Worm, about an inch and a half long, and the thickness of a stout knitting needle. Dr. Gadow states in the "Cambridge Natural History" that "the young ones eat the smallest of Spiders and delicate Insects; later on Earthworms, which they bite into and then suck out before devouring. When six weeks old and well fed they are about three inches long, but it is at least four or five years before they are mature." When they are quite young they crowd around their mother, who looks as if she cared for them.

The second part of the technical name *Anguis fragilis* refers to the ease with which the Slow Worm surrenders part of its tail when it is struck or caught —a self-mutilation (or "autotomy") that often saves the animal's life. What is surrendered can be slowly replaced, though the second tail is not so well finished as the first. This surrender of a part is a very interesting adaptation, and a striking feature is that the rupture takes place not between two adjacent vertebræ, but along a prepared breakage-plane which goes right through a vertebra. We have lingered too long over the Slow Worm, but we cannot leave it without saying that whoever succeeds in making a pet of it will discover something new.

On a dry sandy stretch of the moor with a considerable growth of Hawkweeds, Bladder Campion, Clover, Lady's Fingers, Cocksfoot Grass, and so forth, there are brilliant emerald Beetles which run about with great rapidity and sometimes fly. They are Tiger Beetles (*Cicindela campestris*), about three-quarters of an inch long, with white and yellow spots on the wing covers. They prey upon other insects, including some which are injurious to pasture. They are extraordinarily beautiful, like living jewels. The brilliance is due to thin films of almost metal-like material.

The behaviour of the grubs is very remarkable. They are hatched in the soil, from eggs which the mother beetle has buried there, and they soon set to work to make vertical or sloping burrows, which are sometimes deepened to about a foot. To begin with, a rough burrow is made by pushing the sand to the side with feet and jaws; the miner works head downwards and brings some material to the surface. But soon a more intricate behaviour commences. The larva loads its head and turns a quick somersault in the shaft; it reaches the entrance head up, and with a backward toss of its head it presses the material against the margin. It rights itself and goes head downwards down the shaft to repeat the performance. As the shaft deepens, the material is not brought to the entrance but is pressed into the wall lower down. But there is a continuance of the shovelling, the loading of the head, the rapid somersaulting, the backward tossing, and the pressing of the material into the wall of the shaft. All this has been very carefully watched by Dr. Robert Stäger, a Swiss naturalist, who got the Tiger grubs to do their mining in a glass vessel filled with sand.

We can understand why the shafts are sunk in places where there is vegetation of the kind we mentioned, for the presence of the plants ensures some moisture below the surface of the soil. If the sand were all dry and powdery the walls of the shaft would always be falling in. Another interesting point is that the lower part of the larva's head forms a hard rounded knob, which is used in the most deliberate way to make the wall of the burrow smooth. One may almost say that the Tiger grub has anticipated the plasterer as well as the miner.

The Tiger grub is a carnivore with a big appetite, but it never leaves the burrow, and its mode of capturing its prey is unique. There are hooks on a dorsal protuberance on one of the segments of the grub-like body, and these serve for attachment to the wall of the shaft. The larva fixes itself so that the shield-shaped top of its head forms a sort of door or lid across the shaft just a little below the surface. A small Spider or a little Insect, such as an Ant, comes along, and investigating the depression steps on the lid. The Tiger grub is not in a hurry, and yet it loses no time. When the Spider or the Ant is quite on the top of the grub's head, this is suddenly jerked backwards against the wall of the shaft and the victim is probably killed outright. It is then gripped in the larva's jaws. If the Ant slips down into the burrow, it has to come up again, and it is not likely to escape a second time. Dr. Stäger has given a wonderful description of the spring-like violence of the head jerk by which the small insect is battered to death. When it has killed its victim, the Tiger grub descends the shaft and sucks out the juices. The dry husk is afterwards thrown out with a jerk.

CHAPTER VIII

LAKES AND TARNS

The making of lakes—Lake plants—Fauna of lakes—Tarns and their life—Tarn plants—Adaptations of water plants in general—Hydra—The tarn in winter—Dragon Flies—The Heron—The Dabchick.

FROM the top of the hill we saw many sheets of water—two great lakes, many little lakes or lochans, and innumerable tarns among the Heather and on the moor. The question rises: How are these formed? The geologists give three answers.

The formation of a lake presumes a hollow which gets filled with water unless there is some subterranean escape. The hollow will remain full if the original supply of water—*e.g.*, by rainfall—is kept up, and if the hollow is deep enough. For if it be very shallow, as in a pond, the evaporation may be greater than the supply. Everyone knows how pools dry up.

The first way in which lakes may be formed is by the unequal deposition of material which results in making a dam. We illustrate this for amusement when we make a temporary dam in a little stream. A lake is formed, but when the body of water begins to exert a pressure greater than the dam can bear the dam gives way and there is a flood. Man illustrates this on a large scale when he makes a reservoir by building a great dam across a valley. The deposits which are laid down in nature so as to form dams are very varied; they may be due to moraine materials and boulder clay which glaciers have brought down, or to débris from the mountainside swept down in a flood, or to landslips and screes, or to a stream of lava blocking a valley, or to other causes. A lake sometimes arises in a crater that is not too leaky, and a very interesting kind of lake has sometimes been formed by beavers building a dam across a river. It might be thought that many of these dams would be too full of holes to keep back the water, but we may notice on the seashore that a bank of sand thrown up in a storm often forms a sufficient dam for a lake between it and the cliffs or the dunes. This is due to capillary attraction holding the water between the grains of sand, and we have sometimes seen a temporary dam greatly helped by bands of seaweed. Moreover, while the dam made by moraine materials or by earth carried down from the hill by a flooded stream may be at first rather leaky, the percolating water soon shuts up its own way of escape by depositing clay and fine particles in all the little interstices. Windermere and Ullswater may be mentioned as probable examples of lakes mainly due to barriers of boulder clay (the material accumulated underneath a glacier) blocking a valley.

The second way in which lakes may be formed is by the erosion and solution of hard rock. A glacier filling a river valley may gouge out a deep hollow, and sometimes it is plain that the ice and the rock materials brought with it must have risen over a very hard rock barrier and gouged out a second deep hollow lower down the valley. This has been the case with Loch Coruisk in Skye. Loch Duich, on the mainland opposite Skye, is very deep at the end farthest from the sea, and is probably of glacier origin. When a river slowly dissolves a soluble rock such as limestone over which it flows, it may form a sort of lake on its own course. Sometimes underground streams dissolve out caverns, the roofs of which fall in, thus forming depressions that serve as the beginnings of lakes. There are other kinds of erosion, but we are only concerned with the general answer to the question: How do lakes arise?

The third way in which lakes may be formed is by bending, breaking, or sagging of the earth's crust, so that depressions result. Fractures, displacements, and dislocations of the earth's crust are included by geologists under the comprehensive term "faults," and some of the great lakes of the world—such as Lake Nyassa and Lake Tanganyika—have arisen in connection with faulted areas. The valley of the Jordan is a strip of country that has sunk down between two parallel faults, and the Dead Sea is a great lake which occupies the deepest part of this depression. It is a rock basin, the result of an in-sinking; the surface of the water and the rocky floor are respectively 1,292 and 2,592 feet below the level of the Mediterranean.

The little that we have been able to say in regard to lakes should be read in connection with what has been said in regard to mountains and valleys. The subject should be followed up in such a book as Mr. Philip Lake's "Physical Geography" (Cambridge, 1915).

Around the edge of the lake there are rooted plants, which sometimes occur in belts. Nearest the shore and only partly in the water is the perennial Reed (*Phragmites communis*), growing six to ten feet high, a true grass; the Bulrush (*Scirpus lacustris*), sometimes eight feet high, a sedge; and various Rushes (*Juncus*), which belong to a third family. We may also find some of the following: The Water Plantain (*Alisma plantago*), the Flowering Rush (*Butomus umbellatus*), and the Arrow-Head (*Sagittaria sagittifolia*), all belonging to the same family of Alismaceæ, and most likely to be found on the sides of streamlets entering the lake. Common along the water edge is the Lesser Spear-Wort (*Ranunculus lingua*), a perennial buttercup with elongated narrow leaves.

A little farther out is the zone of Water-Lilies and a belt, like a little forest, of Mare's-tail (*Hippuris vulgaris*), with erect, many-jointed stem and whorled leaves. Farther out still is the slender submerged *Naias flexilis*, whose name means "water-nymph," and there are also submerged species of Pondweed (*Potamogeton*) along with others whose leaves and flowers are on the surface. We found a little lake once the floor of which was covered as far as we could see with a growth of the Stonewort (*Chara*), which gets its name from the amount of lime that it deposits in its cell walls. The two kinds, Chara and Nitella, form a class by themselves, distantly related to Algæ. They are well known for the display of moving living matter that is seen round the inside of the cells when examined under the microscope, and *Chara crinita* is famous because only female plants occur in Northern Europe. The submerged Nitella meadows of Lake Constance occasionally extend to a depth of over fifteen fathoms, beyond which the light becomes too dim for green plants to flourish. On the floor of the lake there are incalculable numbers of very simple plants, such as flinty-shelled Diatoms and curious lime-secreting, blue-green Algæ, which often form tortuous markings on stones. These simple blue-green Algæ (Cyanophyceæ) have got in addition to chlorophyll a blue-green or verdigris-coloured pigment, called "phycocyanin," which perhaps helps them to make the most of the scanty light. Some of them, such as *Anabæna flos-aquæ,* are interesting also because their living matter secretes gas which collects in vacuoles and buoys the plants up to the surface, where they often form large floating masses. There is a kind of Anabæna that enters into a partnership with a little water fern, mainly of tropical distribution, called Azolla. It appears to be invariably present in a cavity in the upper lobe of the bilobed floating leaves of the Azolla, but the meaning of the companionship remains obscure.

The Water Lily (*Nymphæa*) is a good example of fitnesses. It is rooted in the mud and perennial; its shoot is buoyant with air spaces and very lightly built; the broad leaves float on the water, presenting a large surface to the light. The little openings, or stomata, which allow of gaseous interchange with the atmosphere and regulate the transpiration of water-vapour, are confined to the upper surface, whereas in ordinary leaves they are mostly or exclusively on the under surface unless the leaf grows more or less vertically. It is plain that stomata on the under surface of a Water Lily's leaf, which is continually washed with the water, would be useless; and they are absent. An oak-leaf has on each square millimetre of its *lower* surface 346 stomata, but none on the upper surface. A Water Lily has on each square millimetre of its *upper* surface 460 stomata, but none on the under surface. The flower of the White Water Lily is very instructive in showing gradual transitions from the petals to the stamens, reminding us that a flower is built up of four sets of transformed leaf-like parts—(1) the protective steadying sepals, forming the calyx; (2) the protective attractive petals, forming the corolla; (3) the stamens, which bear pollen-making anthers; and (4) the carpels, which bear an egg-cell in each ovule.

Altogether apart from those lake plants of the shore and the floor that we have just spoken of are the constituents of the open-water "plankton"—microscopic Algæ floating at or quite near the surface and multiplying in prodigious numbers. Diatoms and Desmids and blue-green Algæ predominate, including in the last the attractive Oscillarias with remarkable gliding movements. Along with these simple plankton plants there are always microscopic green animals (Infusorians) which have got possession of chlorophyll and are able to use the sun's rays. We cannot understand the animal life of a lake at all unless we understand that these floating meadows are always capturing the energy of the sunlight and building up carbon compounds by that mysterious alchemy called photo-synthesis, which is the most fundamentally important process in the world. The floating meadows thus form the basal food-supply for higher orders of being in the lake. The unicellular Algæ and the green Infusorians are devoured by minute Crustaceans and the like, and these in turn become part and parcel of fishes, often with several incarnations between. It is only thus that the world keeps agoing. The multiplication of the unicellular plants on the surface of the lake is sometimes so prolific that the water comes to look like living green soup. In some cases, where certain kinds of Oscillarias are abundant, the well-known phenomenon of "red water" occurs. There is often a congestion of life in this "water-flowering," but it passes quickly and a balance is restored.

We have discussed the freshwater fauna in another book, the "Wonder of Life," so that we must keep here to a very short statement. The kinds of animals that are found in a lake must depend mainly on the chances that there have been of peopling the water and on the physical and chemical conditions. The chemical composition of the water depends on the nature of the basin and on what the streams bring down. The depth is important in affecting temperature, illumination, and pressure; it also influences the changes of level, for wide, shallow lakes show the loss from evaporation in dry seasons more markedly than compact, deep lakes. Lakes often differ in colour, and this affects the penetrability of the water by light. The colour of the water depends on various factors—*e.g.*, the dust in suspension in the water, the number of unicellular Algæ, and the amount of organic matter brought in from the peat.

By the shore of the lake there are nests of water birds, such as Moorhen and Coot. The shallows are inhabited by a few fishes—*e.g.*, the Miller's Thumb (*Cottus gobio*), by Water Snails and freshwater bivalves, by many insect larvæ and countless small Crustaceans, by simple worms and two or three freshwater polyps, by the freshwater sponge and many unicellular Protozoa—and by other members of a very representative fauna.

The open water of the lake is peopled by a plankton of Infusorians, Wheel Animalcules, Water Fleas, Water Mites, and a few swimming larvæ of insects and molluscs. "In the transparency, the delicacy of build, and the occasional presence of long processes—believed to be useful in drifting—we see adaptations to the open water life."

The third set of animals in a lake are those that live at great depths, which reach a maximum in Lake Baikal—viz., 760 fathoms. The floor of a deep lake is "a region of uniformity, where there is neither day nor night, where the temperature is low and relatively uniform, where the pressure is very great, where there are no movements apart from life, and where there is usually much mud." Since it is dark in very deep water, there are practically no plants except Bacteria and the like, though the floor of the lake is rich in green and blue-green Algæ to the limit of illumination. The deep-lake animals include some unicellulars, various kinds of simple worms, some red-blooded worms, various Crustaceans, insect larvæ and Water Mites, and a few molluscs. "Finally, there are a few fishes like the giant Silurus and its small counterpart the Burbot (*Lota vulgaris*), which is one of the hosts of the young stages of a formidable human tapeworm called *Bothriocephalus latus*, thus linking up the dark depths of the lake into connection with human life."

In an introductory study it is not very profitable to give lists of plants and animals in different haunts, but examples are necessary in order to give definiteness to the picture. A lake often seems very empty of life, but we have to remember that besides those we look for—often in vain—in the shallows, there is a population in the open water and another on the dark or vaguely lighted floor.

Where did these lake animals come from? The answer is threefold. (1) Some are the descendants of forms that migrated gradually from the sea or were transported step by step. This is doubtless true of the freshwater sponges and the freshwater polyps, for there are only a very few different kinds in freshwater and hundreds of different kinds in the sea. The Common Eel comes from the sea and returns to the sea in its individual lifetime, but it does not come back to the freshwaters a second time. (2) It may be that some lakes are dwindling remnants of ancient seas—relict seas in short—or are connected with relict seas by changes of land-level; and that some lake animals are the transformed descendants of original marine animals. (3) Of many lacustrine animals it may be safely said that they are terrestrial creatures which have taken secondarily to aquatic life. This must be true of the Water Beetles and of the Water Spiders. Finally, when a freshwater population is established in any basin the minute eggs or embryos may be spread to others on the feet of water birds, by the wind, and by slow changes in surface relief.

A tarn is a small upland loch, deeper than a mere pond. It is often surrounded by peat and fringed with rushes; its water is often very brown, which means that it is rich in humic acid dissolved out from decaying plant remains.

There are some very interesting plants in the water of the tarn, and best of all is the Bladderwort (*Utricularia*), with beautiful golden flowers which are lifted erect above the surface about midsummer. It belongs to the same family as the Buttercup (*Pinguicula*) of the bogs, but it has no true roots and floats freely in the water. The long, root-like stems bear delicate, needle-shaped leaves and here and there little bladders. These seem to be transformed tips of leaves, and they serve as traps for minute larval Water Snails and insects and for equally small Crustaceans, popularly called Water Fleas, such as Daphnia, Cyclops, and Cypris. The narrow entrance to the trap is guarded by branched hairlike filaments, which perhaps ward off larger intruders. They secrete a little mucilage which is appetising to the Water Fleas. These push their way in and a valvelike door yields before them. As they get inside, however, the door shuts behind them, and it cannot be opened from within. Thus the visitors are imprisoned and sooner or later die. After they are dead and decayed the Bladderwort absorbs the soluble remains by means of delicate fourfold hairs.

Like Water Milfoil (*Myriophyllum*) and some of the Pondweeds (*e.g.*, *Potamogeton crispus*), the Bladderwort forms special winter buds, rich in reserve material. They are formed in autumn, close-packed clusters of bright green leaves, and they fall off the floating stem—which is dying away—and sink into the mud. There they spend the winter resting, but when spring comes they are buoyed up with gas bubbles and rise to the surface to form the long floating stem. Thus we see how the Bladderwort, submerged all but its flower-stalk, ekes out a livelihood by capturing small animals, and how when it dies away in autumn it does not wholly die.

In some parts of the tarn the surface is quite hidden with the glossy floating leaves of one of the Pondweeds (*Potamogeton natans*), which has also thread-like submerged leaves. There are other kinds (*e.g.*, *Potamogeton crispus*), whose leaves are all under water and only the flowers at the surfaces. All of these are rooted in the mud, and this fact, along with their surface flowers, may serve to remind us that all or almost all the flowering plants that live in water have had a terrestrial origin. Most of them have near relatives on shore. It might be thought that the rootlessness of the Bladderwort was against the idea of terrestrial origin, yet there is a terrestrial species of Bladderwort, and the suppression of roots actually occurs in a few land plants, such as *Coralliorhiza innata*, an orchid that lives among rotting vegetable matter and has a running stem that takes on the root's duties. The rootlessness of many water plants is to be associated with the absorption of water and dissolved salts by the general surface of the plant or by a large part of it. There are no roots in the submerged Hornwort (*Ceratophyllum*), a relative of the Water Lilies which are rooted and have floating leaves.

On other parts of the tarn the surface is covered with the Duckweed Lemna. What look like leaves are really flattened shoots, very buoyant and difficult to wet. On the under side there are delicate, white roots which are unattached. As Lemna is a leafless plant, and as its shoot is not submerged, it requires roots for absorption; it thus makes a good contrast with Utricularia, which is, as we have seen, a rootless plant with a long, trailing, submerged stem. Like Utricularia, the Duckweeds form store buds in autumn which sink into the mud and float up again in spring. It is hardly necessary to say that unattached aquatic plants, like Bladderwort and Duckweed, must be restricted to stagnant water.

It is difficult to believe that Lemna is a flowering plant, but careful inspection will disclose on the edge of some of the green discs the tiniest of flowers. They occur in little groups, two male flowers with a stamen apiece, and a female flower with one carpel, the three being surrounded by a hood. There is another kind of Duckweed, called *Wolffia arhiza*, which has still smaller flowers and is rootless. It must be the smallest flowering plant in Britain.

We must not linger much longer over these water-plants, interesting as they are, but it should be noticed that besides the thoroughly aquatic forms like Bladderwort, Pondweed, and Duckweed, like the Water Starworts (*Callitriche*), where each male flower has one stamen and each female flower one pistil, and the Naiads with equally simple flowers, and the Hornworts, there are a number that live in the water without being in any real sense water plants. Such is the Bog Bean (*Menyanthes trifolium*), a member of the Gentian family, with vigorous tripartite leaves and handsome white flowers raised out of the water along the edge of the tarn.

On a high tarn in the North-west Highlands we once saw an extraordinary display of the Water Lobelia (*Lobelia dortmanni*), which occurs here and there in North Europe, a good example of the way in which a member of a thoroughly terrestrial family becomes accustomed to life in water. The flowers have a delicate lilac colour and are raised on slender, tremulous stalks; when hundreds are seen together as we saw them that August day the water seems to be enchanted.

When plants growing in the water lift their flower-heads high, the pollination is effected by insect visitors. We know, for instance, that the golden-yellow flowers of the Bladderwort are visited by long-tongued Syrphid Flies, which carry the fertilising dust from blossom to blossom. In the case of the submerged flowers of some of the Pondweeds the pollen may be carried by gentle currents in the water. But there is a good deal to be found out yet in regard to the pollination of aquatic plants.

Compared with terrestrial plants, those that live in water tend to be rather degenerate. They have gone back in evolution, and yet the retrogressions may be well suited for aquatic life. In his great work, "The Œcology of Plants" (1909), Professor Warming notices the following adaptations among others: (1) Since the whole surface may absorb water and dissolved salts, the roots may be absent, or degenerate, or arrested. (2) Water-carrying tubes are less in demand than in land plants, and therefore but slightly developed. (3) Supporting tissue, such as wood, is reduced or undeveloped because the plants are buoyed up by the water. (4) Air-containing spaces are very abundant and help not only for flotation, but as aids in gaseous interchange. (5) The skin of the submerged parts is very thin and often green. (6) Transpiration having ceased from submerged parts, the stomata are absent or vestigial except from the upper surface of floating leaves. (7) Most water plants are perennial, for seasonal changes are often but little marked in aquatic conditions. Vegetative propagation becomes more important than seed-forming. It is a general fact that great humidity tells against the forming of flowers, while dryness is in its favour.

It is well worth while to collect some Duckweed and Pondweed and Bladderwort and leave them quietly in a dish, to get a glimpse of the small animals to which they give shelter. There are small, slow-going Water Snails, there are Water Mites of great activity and attractive colours, there are larval insects of many different kinds, such as very tiny Caddis Flies, there are minute Crustaceans or Water Fleas, besides Leeches and Threadworms and Planarian Worms and minute, single-celled creatures like the Bell Animalcule (*Vorticella*), forming a fringe on the water weed and jerking itself up and down on the end of a flexible stalk which coils into a spiral when contracted. But none is more interesting than the freshwater polyp, the green or brown or grey Hydra, to which we must pay some attention.

The freshwater polyp was first studied by the Abbé Trembley in the eighteenth century, and it was he who called it Hydra after the mythical monster with which Hercules contended. It seemed a strange name to give to a little tubular animal about half an inch long and the thickness of a pin, but the Abbé had discovered that if the polyp was cut into pieces each part could grow into a whole, and that if one of the six to ten tentacles surrounding the mouth was cut off, it could be rapidly regrown. So he called it Hydra, for it was characteristic of the monster that when Hercules slashed off a part it was at once replaced by another. Trembley was greatly pleased with his discovery, which he studied thoroughly for several years and made the subject of a very interesting book.

The Hydra hangs from the under side of the Duckweed disc. When everything is still it lengthens itself and sways its threadlike tentacles gently in the water. They touch small animals and poisonous lassos are exploded from stinging cells. The small animal is gripped and paralysed, and then the tentacle tucks it into the Hydra's mouth. Sometimes the Hydra shifts its position on the Duckweed without letting go; sometimes it loops along, fixing mouth and base alternately in leechlike fashion; sometimes it leaves the Duckweed altogether and writhes gently in the water. When food is abundant it produces buds, and these may bear more buds; when food is scarce the buds are separated off, and thus the population of polyps increases. But it also multiplies by fertilised egg-cells, only one being produced at a time.

One of the common kinds of Hydra has a brown pigment—*Hydra fusca;* another is greyish; another is green—*Hydra viridis;* and it seems that the green colour is due to microscopic unicellular Algæ which live inside the inner layer cells of the body in an intimate, mutually beneficial partnership which is called "symbiosis." In the sunlight the microscopic green partners are able, like the green cells in the leaves of plants, to split up carbonic acid gas produced by the cells of the Hydra, to liberate oxygen, which is all to the good for the Hydra, and to build up some carbon-compound like starch or sugar which may be utilised, if need be, by the animal partner. This is a simple instance of the interlacing or interlinking of lives, which takes many forms in animate nature.

There are many small water animals in the tarn, but few large ones. It is easier for small animals—just because they are small—to survive the winter, when the surface of the tarn is often covered for a long time with a sheet of ice. But even the small animals lying low in the mud would be apt to perish if it were not for a very interesting property of freshwater. Why does not the tarn freeze solid, which would put an end to most of its tenants? Freshwater is peculiar, though not unique, inasmuch as it expands, instead of contracting, when its temperature is lowered to near the freezing-point. Now this expansion brings the coldest water to the top, thus tending to lessen the loss of heat from the deeper water. The coat of ice, once formed, remains on the surface in virtue of its buoyancy, and if the frost continues it becomes up to a certain limit thicker. But in proportion to its thickening it serves as a shield lessening the loss of heat from the water below. For this reason, then, if the tarn is a true tarn—that is, of considerable depth—the warmer water below is kept fluid, and this makes it easier for the life of water plants and water animals to continue, especially in a resting phase. On the high tarns there is often a mantle of snow on the ice, and this also helps to lessen the further cooling of the water, for dry snow makes a non-conducting garment. Along with this must be taken the fact that many of the small aquatic animals—*e.g.*, Water Fleas and Wheel Animalcules—form specially protected, thick-shelled "winter eggs" which are able to resist difficult circumstances such as severe cold or great drought. Some of the beautiful little animals known as Polyzoa, which live in colonies, form peculiar external buds called "hibernacula" and still more peculiar internal buds called "statoblasts," which are very resistant to cold. In some of the freshwater Polyzoa, like Paludicella, the colony dies down in the winter, but the hibernacula continue the life and start fresh colonies in spring. In others, like Plumatella and Cristatella, the statoblasts float away, and experiments have shown that their power of developing in spring is actually helped by subjection to a certain amount of frost. Life seems often to be the better for a see-saw between activity and rest, between vigorous agency and lying low.

The small creatures of the tarn, higher in the scale of being than Hydra, are Planarian Worms, Thread-worms, freshwater Worms with red blood, a few Leeches, some Rotifers or Wheel Animalcules, and other minute multicellular animals, numerous small Crustaceans, a few Water Snails, and a considerable number of insect larvæ, which become Midges and Gnats, Water Beetles and Caddis Flies, and even Dragon Flies in the summer season. We wish to say a little about the last, which are often to be seen hawking for smaller insects over the surface of the tarn.

For many reasons Dragon Flies command our admiration. The flight is powerful, sometimes rising to sixty miles an hour; it is varied, now skimming the water, again soaring in a spiral, and again sailing over the moor; the two pairs of wings work independently but harmoniously. Like a Wasp, a Dragon Fly can fly tail foremost. The perfection of the flight is associated with the habit of catching insects on the wing, and in this the keen eyesight is also of vital importance. The number of facets and lenses in each compound eye varies from 10,000 to 28,000; and the range at which movements can be detected is said to be up to ten to twenty yards, the limit for other insects being about six feet. They are large-brained, effective creatures.

Another attraction is the colour of the body, for pigmentation combines with physical structure with extraordinarily brilliant results. In red blood we have to do with pigment colouring; in the mother-of-pearl of a shell we have to do with rainbowlike physical colouring (the pounded shell is simply white powder); in the scales of the wings of Butterflies and in the feathers of the Peacock's tail we have a combination of pigmentary and physical colouring, and the Dragon Flies show the same. There are really splendid displays of green, blue, violet, purple, red, orange, and yellow in different species, and the metallic sheen recalls Tennyson's description of "bright plates of sapphire mail." The effect is enhanced by the large gauzelike, unfolded wings and by the glowing eyes. Dragon Flies are able to look after themselves, though birds and trout levy toll, and they can afford a good deal of self-advertising. Brilliant colours are characteristic of safe animals. Moreover, in spite of their frequently large size and their conspicuousness of colouring, Dragon Flies have in their masterly flight a baffling way of disappearing and reappearing in the air.

The Dragon Flies that we see flying over tarn and pond or river are oftenest males; the females usually lead a quieter life among the herbage. The eggs are in most cases laid in gelatinous masses in the water, and sink to the bottom as the jelly dissolves away. The larvæ are extraordinarily voracious and have a long youth, often lasting for about a year, sometimes for several years. Very remarkable is a protrusible food-catching "mask," really the third pair of mouth-parts, which the larva shoots out with great rapidity on passing animals. During the long larval period the air-tubes, or tracheæ, used in breathing, have no openings, else the creatures would drown, but water passes in and out of the hind end of the food canal, and many kinds have also got threadlike or platelike "tracheal gills." In both these ways the oxygen in the water passes into the closed tracheæ and is carried by them into every hole and corner of the vigorous body. Eating much, growing steadily, the larva has to moult its husk over and over again. This moulting is the tax the creature has to pay for its armour, which, being without living cells, cannot grow, and is always becoming too small for the animal inside. There are sometimes over a dozen of these moults. At the last one the larva creeps out of the water on to a reed or branch and the winged Dragon Fly emerges, often at or near the dawn.

There are a few Trout in the tarn, how introduced we do not know. We have seen them leaping at Midges in the evening, and one of them that we caught, with an expert's assistance, had its stomach full of the small Water Snail (*Lymnæus*). There are a few Newts, too, and the spawn of Frogs and Toads is to be found in spring at the shallower end. It may be for Frogs and Trout, or possibly for Eels, that the Heron (*Ardea cinerea*) comes and waits, standing stock-still in the water in dignified patience or walking very gently with stealthy steps. But we never saw one strike at the tarn, and we know that their appetite has a very wide range; it may have been only Water Beetles or Tadpoles that were got.

When a Heron condescends to take to flight on man's approach, it seems to be leisurely, the flapping of its big rounded wings is so slow. But we timed the flight over and over again, and found that the bird covered a mile in a minute. During the high, straight flight the neck is bent like an **S**, and the head rests between the shoulders.

The Heron occasionally nests on the bare hillside, or on crags, or among reeds; but the favourite site in Britain is on high trees, and there a heronry may be founded. The nest is a large platform of sticks with a lining of twigs and grass; there are three or four large bluish-green eggs. It is through the summer that the heronry is peopled and it is sometimes noisy; in winter it is hardly more than a rendezvous, for the Heron becomes more or less solitary. The parents feed the young ones on fish.

The Heron is one of our larger British birds, attaining a length of three feet, and everyone must admire its statuesque appearance. We like Mr. Beebe's description: "Herons are the 'still-fishers' of the bird world, and stand in the shallows, silent and motionless as the reeds around them, with their lance-like beaks in rest and their necks at a hair-trigger poise." They say that when a Heron is cornered it throws itself on its back, as some birds of prey do, grips its assailant with its uplifted toes and makes savage dagger thrusts with its sharp and powerful beak. A peculiarity which the Heron shares with Parrots and a few other birds is the possession of "powder-down" feathers. These occur in thick patches, chiefly on the breast, under the ordinary feathers; they are strange, quickly growing down-feathers, that break into white greasy powder at the tips. This powder is distributed through the French-grey plumage, and it is believed to keep the ordinary feathers clean and in good condition. A widespread story that the powder-down patch is luminescent is without basis.

There is another bird of great interest that we have seen at the tarn, the Dabchick (*Podicipes fluviatilis*), otherwise known as the Little Grebe. It has a peculiar right to a place in this study, for it sometimes breeds on little lochs high up on the Scottish hills, and, besides, it is a very attractive bird. It is about nine and a half inches long and of a predominantly brown and grey colour. The food consists of small fishes, aquatic insects, and Tadpoles, eked out with water plants. When the loch or lochan freezes in winter, the Dabchick shifts its quarters to the low ground or even to the shore. Like other Grebes it swallows feathers along with its food, just as Hens swallow gravel. The Dabchick flies and runs very effectively, but its swimming and especially its diving cannot be overpraised.

The nest is large for the size of the bird, and consists, as in other Grebes, of a mass of water weeds, usually floating and moored to growing plants. As the weeds ferment there is some heat produced, which will help in the incubation of the eggs. These are creamy-white but often stained, four to six in number, and rather pointed at each end. The brooding bird has the habit of rapidly covering them with water weed as he or she leaves the nest, and this probably helps to keep them warm during the parent's absence.

The young Dabchicks are able to dive as soon as they are hatched, and they use their wings as well as their legs under water. But while they are thus precocious, they are very carefully tended. The parents sometimes carry them about on their backs, but oftener it is under the wings that they find safety. That is their usual position on the nest; and it is said that the male bird does most in the way of bringing in the food. If danger is great the parent bird may dive with the young ones pressed close underneath the wings, and reappear among the weeds where concealment is easy.

CHAPTER IX

A MOUNTAIN STREAM FOLLOWED TO ITS SOURCE

Geology of the stream—The making of a valley—The roving Otter—Water Voles and Water Shrew—Mole-hills in the meadow—The Dipper—Small fry in the stream—Eels and Niners—Glow Worms—An Ant hill—A waterfall—The source.

IT is a delightful experience to follow a stream to its source, and we do not wish to interfere with the pleasure by insisting on "what one ought to see." But if one has time to rest and peer into things, "scrutinising," as the great French naturalist, Henri Fabre, called it, the appreciation of the beauty will be increased, not diminished. As we followed a rather steep mountain stream one day we came upon a waterfall of twenty feet or so, and as we diverged a little to circumvent it we suddenly saw a magnificent Royal Fern (*Osmunda regalis*), growing in thick shade and plentifully sprinkled with spray from the fall—

> Plant lovelier in its own recess
> Than Grecian naiad seen at earliest dawn
> Tending her font, or lady of the lake
> Sole sitting by the shores of old romance.

Now beauty is a peculiar quality in things and creatures and works of art, that calls forth a peculiar joy in those who perceive it, and, frankly, we do not think that our æsthetic delight was in any way lessened by our knowing a little about the Royal Fern—that it is a scion of an ancient stock, that it is the largest as well as the most graceful of European Ferns, that it shows an almost diagrammatic contrast between the foliage part, which keeps the plant agoing from day to day, and the multiplying part, which produces the spores—the spores that in a roundabout way secure the continuance of the race of Royal Ferns. For the tiny spores that are scattered about by wind and by runlets of water give rise to a generation of small green leaflike plants, called "prothalli," which bear minute male and female organs. From the fertilised egg-cell of the prothallus, which lies more or less flat on the moist soil, there grows the stately fern plant, the spore-making generation. This is a very remarkable complication of the life-history of the Fern, and is known as "alternation of generations"—the alternate occurrence in one life-history of two different forms, differently produced. It is well illustrated by Mosses and Horsetails; it is much disguised in flowering plants. It is interesting to know that the same alternation occurs in the life-history of many zoophytes, in the common Jellyfish, in some Worms like the Liver Fluke, and in a number of other animals.

Before our stream joins the river it lingers in a meadow, where Cuckoo Flowers (*Cardamine pratensis*) are common in spring, and it is extraordinary the way it wriggles about, now to one side and now to another, in the soft alluvial soil. Longfellow has recorded his impressions of a river in the well-known lines:

> And silver white the river gleams
> As though Diana in her dreams
> Had dropped her bow
> Upon the meadows low.

But what we see in this flat stretch is like a silver serpent with a long sinuous body. There are several places where a bend has turned back on the main course and almost touched another higher up. If it did this there would be a grassy island formed. We see that the stream eats into the back on its deeper, swifter side and deposits sand on its shallower, slower side. This goes on until it meets some obstacle on the deeper side or until the falling in of a stretch of bank deflects the course, and the eating in commences on the other side. So year by year the winding stream shifts its course through the meadow.

We suppose that the line of the stream was very long ago a line of weakness in the earth's crust—a crack, in short; but, given a beginning, we can understand from the behaviour of the stream to-day how the bed has been deepened and a beautiful gorge cut back into the hill. What do we see?

Here are the Falls of Niagara in miniature. We see that the rock at the foot of the waterfall is of softer material than that above. It gets eaten away more rapidly just because it is softer, but there is also the wear and tear of the shifting stones which the whirling water uses as tools. Just as one can get in behind the tremendous curtain of falling water at Niagara, so here one can see that a miniature cave is being carved out behind the cascade. Some day this will have been eaten in so far that the roof falls in and a big slice breaks off from the undermined harder rock above. The top of the fall is shifted back a little, nearer to the hills. The fallen rock, broken into pieces, supplies materials for new tools for more sapping and mining. What takes place at a waterfall occurs also on the banks of the stream: there is gouging and undermining and falling in and sweeping away; and this has been going on for ages. Of course there are more violent ways of deepening and broadening the bed—days of flood notably, when all the stones seem up in arms.

When we were walking one day with an old naturalist up the side of the river—not this little mountain stream—he pointed to an island covered with small Alder-trees and said: "I have seen the whole of that island made." It was in the lee of a large island, and our friend had witnessed in the course of forty years the gradual accumulation of sand and gravel in the sheltered area where the water flowed slowly. Probably the smaller island was for a time only a downstream promontory of the larger one, and then a peninsula, and finally independent. We meant to have asked, but the old naturalist began to say something about a Kingfisher, and we forgot about physiography.

In many parts of the country we may see what is called "crag and tail." A high boss of hard rock has been surrounded by a glacier which gouged out a deep hollow in front of the obstacle and on each side, but left in the protected lee a long slope or tail. The glaciers have passed away, but their handiwork is seen in "crag and tail." And it is very interesting to look in the bed of the stream for the same sort of thing, only on a very small scale, and with a swift flow of water instead of an imperceptible flow of ice. We see a firmly fixed hard stone, at the upstream end of which there is a deep excavation, while at the sheltered downstream end there is a sloping "tail" of sand.

The same sort of thing is familiar at the upstream and downstream ends of the middle pier of a bridge spanning a rapidly flowing river.

There are many other physiographical features to be studied in our stream besides the **S**-shaped windings in the meadow, the cutting back of the waterfall, and the little examples of "crag and tail"; but these may serve as a beginning. There is a pleasure in looking at the pot-holes, where a hard stone shut up in a corner has been whirled round and round so many millions of times that it has worn out a bowl-shaped cavity in the rock. Many of the pot-holes have lost their stones—were they worn small and swept away in a flood, or were they lifted away by ice? Other pot-holes have been left on one side by a change in the line of the stream, and in one of them there is a Golden Rod (*Solidago officinalis*) growing.

When the earth's surface is folded like a tablecloth forced into ridges, the heights form mountains and the troughs form valleys. But it is very seldom that this is the explanation of a valley. Sometimes, indeed, the valley of to-day corresponds to the line of the original ridge and not to the line of the original trough.

When two parallel breakages or faults occur in the earth's crust and a strip of country falls in, if one may so say, a long trough may be formed; and the Jordan Valley was, to begin with, a depression of this sort, and is known as a "rift valley." But it is not very often that this is the explanation of a valley.

The earth's crust is made up of heterogeneous materials, different in hardness, chemical composition, and other qualities, and the slow weathering effected by the air, the rain, the frost, and other carving tools is unequal. Some parts stand out more than others, and the rain begins to follow particular lines which twist about seeking the paths of least resistance. These lines may, indeed, be determined in some measure by original ups and downs on the crust, or by a line of weakness such as a fault; but it seems that most valleys began in a commonplace way, such as we may often see mimicked when the water of a pool on a gently sloping sandy shore flows out after the receding tide, or when a heavy fall of rain makes a flood on soft soil. It seems, then, that the *beginning* of the carving out of valleys is due to the atmospheric weathering agencies operating on a crust which is more resistant in some parts than in others.

When a valley has got started it is deepened and widened in various ways. The water of the stream may dissolve the rocks over which it flows, or it may carve at the bed and the sides by means of the pebbles and sand it rolls along. It may undercut the banks so that they fall in, or it may undercut below a waterfall so that the harder rock above comes tumbling down. "The water wears the stones" according to the adage, but it is more correct to say that the water's tools are the stones, large and small, which it is able to move.

At its head a stream usually tends to cut farther and farther back into the hill. The stream's "curve of erosion," as it is called, is steepest there, and the rivulets made by the heavy rain hurry downwards, carrying the weathered-out pebbles with them and carving as they go. The rivulets cut backwards into the hill and they enable the stream to tap fresh springs, beyond those with which it started. Springs simply mean more or less permanent outflowings of the rain which has seeped into the upper part of the hill and been kept as in a sponge. In keeping up the supply when there is no rain, the literal sponges of Bog Moss play, as we have seen, a very important part.

In the development of some valleys a glacier may have helped, carving especially by means of the stones which it carries in its grip. What are called "hanging valleys" are especially common in glaciated regions, and glaciers have probably helped to make them. The curious term is applied to side valleys which open, not into the bed of the main valley, but high up on its sides, so that the tributary stream tumbles into the main river by a series of rapids and waterfalls. This is due to the main valley having been eroded more rapidly than the side valleys. As hanging valleys may occur in districts which are not glaciated, the inequality in the rate of erosion must sometimes be due to causes independent of glaciers. To follow up the enquiry, the student should consult books like Lake's "Physical Geography" (Cambridge, 1915) or Sir Archibald Geikie's "Class Book of Geology" (London, 1907).

Just where our stream joins the river there is a thicket of Osiers and small Alder-trees, making a sheltered spot. On the clean gravel there we found a large Trout not long since killed, with a big piece bitten out of it just behind the head. We do not doubt that an Otter had been disturbed at its meal. There is no doubt that the Otter accounts for a good many fish, but there should be enough and to spare; and who will not wish good luck to one of the most interesting of British mammals? So keen of sense, so strong of limb and jaw, so adventurous in its hunting, so perfect in its woodcraft, so resourceful in face of danger, such a creature deserves well to live. It is a restless rover, a good fighter, and fond of blood, but the other side of the picture is the thoroughness of the mother's care. She will hardly leave the young ones save for a hurried meal; she carries them to a sunny bank when they are big enough and begins to teach them the alphabet of significant sounds and scents; she shows them how to swim and dive, how to lie low, how to catch and how properly to eat Trout and Eel, Frog and bird; she plays with them and she will die for them. One of Nature's voices is: "Struggle, Endeavour, Struggle"; but the answers-back to difficulties that make up the struggle include caring for others as well as caring for self. Otters survive because they are strong and clever, but also because they are such good mothers. They have such a capacity for self-forgetfulness.

The lower reaches of the stream, where it lingers in the meadow, are the homes of two mammals, one well known and one little known. The first is the Water Vole and the second is the Water Shrew. Everyone knows the Water Vole (*Microtus amphibius*), and almost everyone calls it the Water Rat. It is easy to see, however, that it has a broader head and much shorter ears than a Rat has, and that the tail, which is much shorter than a Rat's, is covered with close-set hairs. Its winding burrows are abundant along the banks of the stream, and they often have an under-water as well as an above-ground entrance. The creature swims and dives well, and feeds mainly on the roots and stems of plants, like the iris, that grow by the sides of the water. It often makes excursions by night to the fields near by. One sometimes sees it sitting squirrel-like near the door of its burrow munching some piece of root which it holds in its paws, and a rarer sight is the mother swimming with a young one in her mouth. Water Voles do not multiply so quickly as Rats do, and apart from breaking down the banks of the stream they are not very harmful.

The Water Shrew (*Crossopus fodiens*) is a little black and white animal, about three inches long in body with two more to the tail, much commoner than most people think. It is not a rodent like Rats and Voles, but an insectivore like Mole and Hedgehog and Land Shrews. So it lives on small insects, Crustaceans, and Snails, that it finds in the water, and, apart from an occasional dinner of fish fry, it does not do any harm at all. It makes long winding burrows in the banks, with a rounded chamber at the far end. There in spring the five or so young ones are born in a grass-lined nest. They become very pretty little creatures and play about on the banks. Indeed, the Water Shrew is a very engaging animal, which deserves closer study. Its swimming just at the surface, half in, half out, is very neat, and makes hardly a ripple. Although the creature is doubtless derived from a terrestrial stock, common to it and the ordinary Land Shrews, it is now so thoroughly at home in the water that it will rarely leave it except to enter the burrow.

There are Common Shrews and Field Voles in the meadow, but the creature most in evidence, though seldom seen, is the Mole. Without wishing to make a mountain of a molehill, we must admit that there are too many of them here. Partly, we suppose, because there are so many Earthworms, and partly because the soil is very easily worked. We must not linger too long, but it is interesting to think of the Mole as a bundle of adaptations. That is always one of the rewarding ways of thinking about living creatures. The hand, turned outwards, forms a broad shovel, and it is helped by an extra "sickle" bone to the inside of the thumb. The shoulder girdle is very strong, and the muscles fastened to it are like those of an athlete. The long, muscular, sensitive snout is well suited for probing into the ground and is strengthened by a special bone near the tip. The eyes, like tiny black dots and difficult to find, are hidden among the hair and thus saved from being rubbed; the absence of a projecting ear-trumpet is an adaptation to reduce friction in burrowing; and there must be some fitness in the way the short hairs stand out vertically without any "set." There will be great gain from our studies if we strengthen the habit of enquiring into the fitnesses of animals to the diverse circumstances of their life.

Leaving the meadow, we pass on to the hillside, and the stream changes its character. It is much more in a hurry and there are many little falls. The bed is rough with stones, often projecting on the surface and breaking the current into bubbles. This is one of the stretches where we always see the Water Ouzel or Dipper, and we believe that it is the particular preserve of a particular pair who are oftener apart than together. It is interesting to notice that although the brilliant white breast makes the bird, which is rather smaller than a Thrush, very conspicuous in certain situations, it conceals it in others, being so like white foam.

The Dipper (*Cinclus cinclus*) is said to be related to the Wrens, but it has found a vacant niche in streams and has learned to walk and to fly under water. It suddenly disappears under the surface and may be seen clinging with its toes to the stones and working its way upstream, beating with its short wings. The head is bent downwards, exploring the bed of the stream for water animals such as insect larvæ, small Crustaceans and Molluscs, and very rarely a young fish. As Dippers destroy little creatures that devour fish eggs and fish fry, they are on the angler's side, and it should be sacrilege to kill one. The nest is built under a bridge, at the mouth of a culvert, sometimes under a waterfall, and in similar places; it is glued on to the support and consists in many cases of two distinct parts—an interior made of dry grasses and leaves, and an outer envelope of felted moss, which keeps the wet out. The four to six eggs are pure white, but without the gloss of the Kingfisher's. The cock-bird courts his mate with great zest, and there is often a good deal of difference of opinion between them. He sings a short wrenlike song, but this is not confined to the courting time; it is a pleasant sound in winter, which the Dipper meets with cheerfulness. The young birds are able to swim right away, but they do not seem to take to the water instinctively. It requires a tumble or a push into the stream to awaken the inherited capacity. After they are able to fend for themselves they seek out a stretch of stream to be their own preserve. There are scores of interesting things about these birds, but the most interesting is just this, that they are perching birds which have tackled the problem of aquatic life and have solved it.

The Water Ouzel is fine in itself, and we often hear it in days when there are few songs. Mr. Robert Gray writes in his "Birds of the West of Scotland": "In early spring, the male birds may be seen perched on some moss-covered stone, trilling their fine clear notes"; and again: "I have stood within a few yards of one at the close of a blustering winter's day, and enjoyed its charming music unobserved. The performer was sitting on a stake jutting from a mill-pond in the midst of a cold and cheerless Forfarshire moor, yet he joyously warbled his evening hymn with a fulness that made me forget the surrounding sterility." Ruskin quotes these sentences in "Love's Meinie," and has a good deal to say about the bird, making, however, the astonishing statement: "I am sixty-two, and have passed as much time out of those years by torrent sides as most people. Yet I have never seen a Water Ouzel alive" ("Love's Meinie," p. 99; see also p. 194). Yet the bird is found in Britain, Mr. Howard Saunders tells us, "wherever there are rapidly running rivers, or brooks rippling over rocks and stones."

It is a good rule on natural history excursions to turn stones upside down and then put them gently right again. For it is under loosely lying flat stones that many creatures lurk, and this is particularly true of the stream. When we lift up some suitable stones from the stretch that the Dipper frequents we find a crowded life. There are freshwater Snails, for instance, like Lymnæus, with its shell in a spiral, and Ancylus, like a tiny limpet. There are freshwater Crustaceans, like *Gammarus pulex*, one of the scavengers of the bed of the stream. There are insect larvæ of many different kinds, young May Flies, young Stone Flies, young Caddis Flies in their jackets of stick fragments and tiny pebbles. There are several different kinds of Leeches, one of which, called Clepsine, carries its young ones about with it attached to the ventral surface—one of the humblest illustrations of parental care in the animal kingdom. There are small flat Worms called Planarians, gliding along mysteriously like tiny pieces of leaf; they are moving by means of microscopic lashes or cilia that cover the surface of their filmlike body. We have noticed that some of these are found high up the stream, halfway up the mountain. There are freshwater sponges on the stones and bank posts of the river, but we never found them in the lesser stream. But besides these visible creatures —and we have only mentioned a few samples—there are scores and scores too small for the naked eye to see.

Towards the end of May the Elvers or young Eels come up our river, but the date for different rivers varies according to the distance of the mouth from the Atlantic. These Elvers that come up in thousands, hugging the bank of the river and hiding under stones when the sun sets, are already about two years old, their earlier youth being spent in the open waters of the ocean. We must not tell the story now, but the Elvers explore the tributaries of the river, and those that are successful in finding good hunting-ground where there are fishes in abundance grow and prosper. After half a dozen years or more they are fullgrown and become restless. They leave their feeding-ground —sometimes a millpond, sometimes a slow-flowing reach of river or stream—and they descend the river to the sea, travelling quickly by night. They seem to go down to the deep water of the Atlantic Ocean, from beyond the Hebrides southwards to the Azores, and as they never come back again they probably die after spawning. In all likelihood they are deep-sea fishes which took long ago to exploring the freshwater, just the opposite of the Salmon, which is a freshwater fish that has taken to feeding in the sea. There is a migratory impulse engrained in the Eel's constitution, and the particular feature that we wish to call attention to is the strength of this hereditary impulse. It is not following the line of least resistance to swim up against the stream, and yet the Elvers must do it. It is extraordinary the persistence with which they overcome obstacles, even circumventing waterfalls. They get up into Lake Constance, though that is above the Falls of the Rhine; they get up into Lake Superior, though that is above the Falls of Niagara. The conundrum is a little difficult, but the answer is in the word "circumventing," and it is illustrated on a small scale in regard to some of the waterfalls on what we are calling our stream. The young Eels get up somehow, wriggling on the moss-covered rocks by the sides of the cascade, wriggling up even among the wet grass and herbage. Up at all events they do get.

Very different from young Eels and yet sometimes confused with them are the "niners," or larval Lampreys. We found about twenty in a backwater pool, in what was really part of the flood-bed of the stream. They were the young of the Brook Lamprey (*Lampetra planeri*), and there are two other kinds in the river—the Sea Lamprey (*Petromyzon marinus*), which *usually* goes down to the sea, and the River Lamprey (*Lampetra fluviatilis*), which *sometimes* goes down to the sea. The spawning of all the three kinds occurs about midsummer, and the sticky eggs are laid in a nest of stones which saves them from being washed downstream. The young ones are quickly hatched and they seek out places where the water flows slowly and where there is an abundance of minute aquatic creatures which are swept through a sieve into the toothless, horseshoe-shaped mouth. They are curious old-fashioned creatures, with hidden and rudimentary eyes, with seven small gill openings in a groove, and an unpaired nostril high up on the top of their head. They remain young for three or four years and then change into Lampreys; the mouth becomes circular and abundantly furnished with horny teeth; the eyes develop and there are remarkable internal changes. They fasten themselves to fishes, taking a very firm grip and using a toothed muscular piston, which we can hardly call a tongue, to rasp a hole through the skin. One must admit that if the word "fish" is to mean anything precise, we must not call Lampreys fishes. They are jawless, limbless, and scaleless, their gills are in peculiar pockets, and their unpaired nostril is altogether peculiar. In fact, they belong to a class of Round Mouths, or Cyclostomes, which also includes the Glutinous Hag (*Myxine*) of the sea. Almost the only feature that they have in common with Eels is that the adults die after spawning. We have found even the big Sea Lamprey, which is as long as our arm, lying spent by the side of the river, an illustration of the fact that the beginning of new lives is often the ending of the old. But it is time we were getting farther up the stream.

Where we follow the stream upwards and turn into the glen, which is at first widely open, there is on one side a grassy and mossy bank which passes into a pine-wood at the top. There, late in the midsummer evenings, we have watched the Glow Worms flashing their signals. Our stream is in the West of Scotland.

Glow Worms (*Lampyris noctiluca*) are Beetles, and although there is a little power of light production in the eggs, the larvæ, and the winged males, it is mostly the wingless females that glow. These are dark, flattened, short-legged, rather grublike creatures, nearly half an inch long. They lie quiet during the day and climb up on to the herbage in the evening, flashing forth a greenish light from the under surface of the tail. The light is almost continuous, but it may be seen to wax and wane. It is likely that the significance of the light is to attract the attention of the males, who fly about vigorously. The light is produced from a yellowish substance inside the tail, which is well supplied with air tubes. Some say that what happens is a rapid burning away or oxidation, while others maintain that there is also a rapid fermentation process, as seems almost certainly the case in the related Fire Flies. It is certain that oxygen and water are essential to the production of the light. One must not make too much of a mystery of it, for just as rapid changes that go on in our muscles, keeping them fit for contraction, result in producing heat, and just as changes in the electric organs of certain fishes, such as the Torpedo of the Mediterranean, result in giving electric shocks, so chemical changes in the Glow Worm's tail result in flashes of light at the rate of over one a second. Man has invented no lamp that can compare with the luminescence of the Glow Worms and Fire Flies, for very, very little of the energy of the insect's organ is wasted in producing heat. It is almost all what may be called "cold light," and it might be taken as an emblem of the light of science, which as such has no warmth of feeling in it! It may be noted that there is no phosphorus in the substance which gives out light in the Glow Worm, so that the word "phosphorescence" should not be used in this connection.

There is much that is still uncertain in regard to the "Glow Worm golden in a dell of dew," but we know that the big-eyed males gather to the female's lamp, and that she shines more brightly when they come near. Other living lights may serve other purposes, but those of Glow Worms are surely love signals. When mating is over the female crawls into the wood and prepares for maternity. It has been noted that the young Glow Worms would be useful in gardens, for they are very fond of small slugs. What the full-grown beetles eat, if they eat at all, is uncertain.

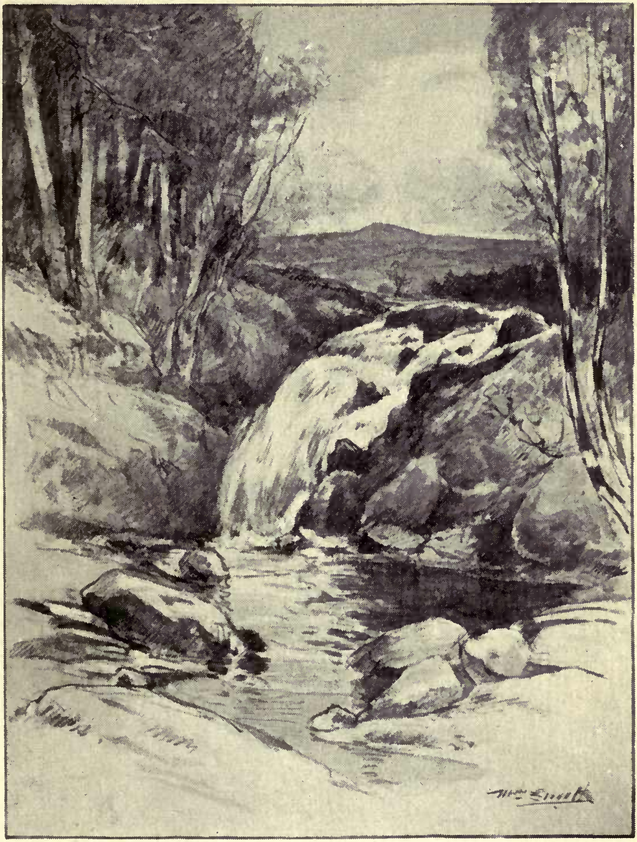
On the outskirts of the pine forest into which the mother Glow Worms retreat, there are enormous Ant hills, fully three feet high and six feet in circumference. They are the largest we have ever seen. They are built mainly of the withered twin needles of the Scots Pine, with fibres and small twigs and some resin here and there. If we open the hill a little we see the hurry-scurry of the worker Ants hastening down the numerous passages. If we are hard-hearted enough to go deeper we see almost every worker carrying a white sausagelike thing in its mouth. These white things are popularly called ants' eggs, and are sold under that name as food for birds and fishes. They are not the eggs, however, which are much smaller, but the developing pupæ, turning into fully formed insects. The workers are trying to carry them into safety in deeper recesses of the hill. Out of the egg comes a minute white grub, which is fed and grows, and moults, and eventually, after several moults, sinks into the quiescent pupa stage. Inside the pupa case the larval body undergoes a living dissolution and is built up again on a new plan—that of the adult. Out of the pupa case there emerges the fully formed and full-grown Ant, with a brain which Darwin called the most marvellous atom of matter in the universe, it has such a rich repertory of inborn capacities for doing effective things.

We must not delay at the ant hill, which is some yards from the stream any way; but we cannot pass by without noticing five things. (1) Just as in a bee-hive, there are here—(*a*) the fertile females or queens, (*b*) the usually sterile females or workers, and (*c*) the males; and among the workers there is considerable division of labour. (2) It is by instinct, or inborn inspiration, and not as the result of laborious intelligent learning that Ants follow their daily routine, and yet along certain lines they seem capable of learning not a little. Thus, prolonged experiments have made it practically certain that a good deal of the Ants' ability to find their way home from a considerable distance is due to practice in combining olfactory, visual, tactile, and even muscular impressions which serve as finger-posts. (3) Although ant hill may make war on ant hill, there is general harmony among the members of the same community, and there are certain conventions, such as feeding the hungry, which appear to be almost invariably respected. (4) It is, so to speak, a satisfaction to the workers to labour for ends which are other-regarding rather than directly self-preservative or self-rewarding, but it is very interesting to notice some recent researches which show that in certain species of Ants the workers receive from the larvæ, when feeding them, tiny sips of a mouth-secretion which seems to be appreciated like an elixir. (5) Repeatedly in these studies we have referred to the interlinking of the interests of different kinds of creatures, and there are many illustrations to be found in the ways of Ants. Thus some of them inadvertently sow a percentage of the seeds which they collect for food; a few of them keep Aphides, or Green Flies, as domestic animals; some of them have slaves and others have pets. The circle of an Ant's life cuts many other circles. It seems, for instance, that several of the Little Blue Butterflies, like those flitting about on the Heather, require to sojourn for a while as caterpillars in the Ants' nest. We venture to refer for continuation to our "Wonder of Life" (1914).

The little valley of the stream has become a gorge, and round one of the many corners, each one giving us a surprise though we have followed the stream many times, we come on the waterfall. It is only about twenty feet high, but almost sheer, and it is not size only that gives impressiveness and beauty to a waterfall; it is the setting of the leap, the changefulness, and sometimes the pleasant breaking up into a succession of cascades. *What makes a waterfall?*

Mr. Lake's answer is so clearly worded that we venture to quote it: "If a hard bed dips gently down the stream, the river, in passing over it, will generally form rapids rather than waterfalls. But if the hard bed is horizontal, or dips gently up the stream, the river will wear away the softer rocks beneath it, the hard bed will overhang, and a waterfall will be produced. The falling water will continue to undermine the hard bed, and from time to time blocks of the latter will be broken off and the waterfall will gradually recede upstream." This is what has happened here; our twenty-feet waterfall is a miniature Niagara, and the gorge we came through is like the Niagara gorge, due to the backward cutting being more rapid than the erosion of the sides of the valley by rain and the other atmospheric agencies. Mr. Lake goes on to point out, however, that "if a hard bed, or an igneous dyke, runs vertically across the river, the soft rock on the downstream side will be rapidly worn away and a waterfall will be formed. But no undermining of the hard bed is possible. The river will gradually cut its channel deeper, both in the hard and soft rock, and the waterfall will not alter its position" ("Physical Geography," p. 249).

There are some beautiful shade-plants growing in the recesses near the waterfall; these are well-represented by the Golden Saxifrage (*Chrysoplenium*), the Woodruff (*Asperula odorata*), the Moschatel (*Adoxa moschatellina*), and the Hart's-tongue Fern (*Scolo-*



THE WATERFALL.

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pendrium vulgare). They get so little direct light that we wonder that they are able to live, for light is essential to the building up of sugar and other carbon compounds in the green leaf. Light that has filtered on to the shade plants through other green leaves would not be of use, for in passing through the first green screen it would lose those rays that are of importance. In ordinary cases the shade plants must utilise the light that gets through gaps in the leafy screen above; in a few cases, as in the "Luminous Moss" (*Schistostega*), there are special arrangements for making the most of the scanty light.

A roundabout climb is needed to get above the waterfall, and then we find ourselves in a very different scene—an open moorland with peat and Bog Moss and Heather. The stream has still considerable volume, but it has no great speed except after heavy rain or a rapid thaw in spring. It receives many little tributaries, and we find that the spongy ground means heavy walking. We follow on, however, to where the hill begins to rise steeply from the moor; we reach what they call the "wells," a number of small springs with deliciously cold water bubbling out from beneath boulders. We have found the source.

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